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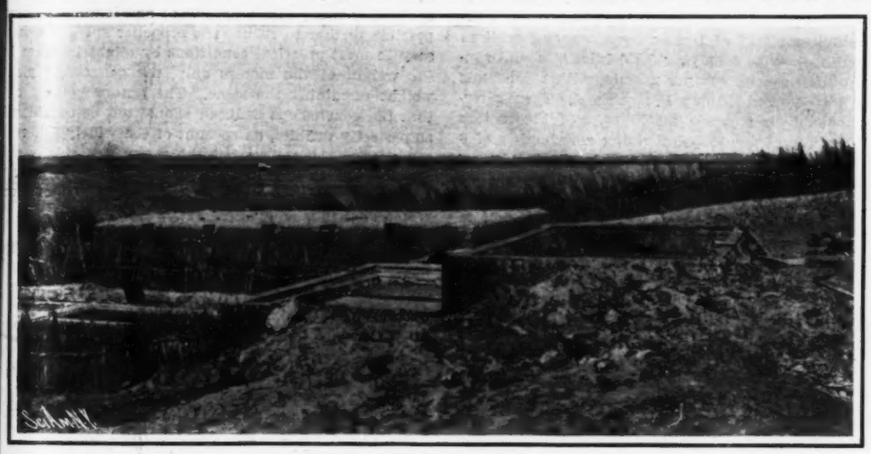
ARTESIAN BORE IN THE DESERT. THE CANVAS SHIELD PREVENTS THE SAND FROM FILLING THE POOL.

PRIMITIVE BORING MACHINE OF THE NATIVES.



ALUM LEACHING TANKS NEAR KHARGA OASIS.

A VIEW IN THE KHARGA DESERT.

AN OVERFLOW FROM AN ARTESIAN BORE AT KHARGA OASIS.

HUGE SAND DUNES SKIRTED BY THE RAILROAD IN THE MIDDLE OF THE DESERT.

THE LIBYAN DESERT RAILROAD.—[See page 120.]

STEAM-ELECTRIC MARINE PROPULSION.

THE EFFICIENCY OF A POSSIBLE SYSTEM OF THE FUTURE.

A PAPER, by Mr. William P. Durtnall, entitled, "The Generation and Electrical Transmission of Power for Marine Propulsion and Speed Regulation," was read before the Institute of Marine Engineers at a special meeting. Leading up through the stages of development in reciprocating engines to the adoption of steam turbines in ship propulsion, the author pointed out the few but important disadvantages involved in the direct-coupled turbine. It was necessarily designed to run at very low speed to permit the use of a propeller of high propulsive efficiency, and consequently its diameter and weight were increased to a very great extent. The blade clearance was also greater, to allow for expansion and contraction, involving higher consumption and leakage of steam. There was also the difficulty of reversing, and the increased consumption per horse-power when working below full load and speed. Tests on the "Lusitania" had shown an increase in consumption from 14.46 pounds to 26.53 pounds of steam per shaft horse-power per hour when speed was reduced from 25.4 to 15.77 knots. The ability to maneuver was of little importance with ships making long runs, but very important in short-voyage vessels and ships of war, in which frequent starting and stopping and maneuvering in and out of harbor or in squadrons was necessary. To meet these requirements, astern turbines, of about one-third the total ahead power, and coupled to separate propeller shafts, were carried. The dead weight was therefore only partially utilized. Full power speed at reverse was only possible with a complete duplication of turbines, but the safety thereby secured was possibly of more importance in short-trip vessels than the increased weight involved. In order, therefore, to secure the complete success of the steam turbine for ship propulsion, means would have to be devised to allow the turbine to run at high speed and the propellers at comparatively low speed, so securing economy in both cases, and also to provide reverse motion for all shafts. After alluding to mechanical, hydraulic, and compressed air devices which had been tried and found inefficient, the method of electrical power transmission was stated to be that in which the greatest possibilities lay. This system supplied the very elements required to take advantage of high-speed turbines, saving weight and securing high economy in steam, by utilizing these to drive electric power generators, the current so generated being used to drive low-speed motors coupled to moderate-speed large-bladed propellers of high efficiency. This method of transmission would do away with the necessity of extra turbines, shafts, and propellers for reversing. The turbine generator would always run in one direction as regards speed rotation, while the motor could be reversed and efficiently run in either direction. Moreover, the direction of rotation and speed could be instantly changed to meet all conditions in practice, and this very important feature could be utilized with the utmost economy even at the lowest speeds and powers. The electric motor, as well as the turbine and generator, had also the capability of standing very severe overloads for short periods without damage. The large power conductors need only be broken under no-voltage conditions, and the control could be operated from the bridge when desirable.

The author was of opinion that for marine propulsion electrical power transmission could only be successfully effected by polyphase alternating currents, with synchronous generators and squirrel-cage induction motors, on account of the low cost and weight per horse-power, absence of commutators, and high efficiency of these machines. In generators of this type the armature was a stationary closed ring, with the winding imbedded in slots round the inner face, inside which the field magnet revolved. The main current was generated in the stationary ring and taken off direct, without any of the intermediary devices necessary when collecting current from a rotating source. The field magnet received its exciting current from a small direct-current machine, mounted on the generator shaft. This current, which only amounted to about 2 per cent of the generator output, was delivered to the revolving field through simple collecting rings. It was of importance to note the exceptionally high efficiency, light weight, and low steam consumption of such combinations as converters of mechanical into electrical energy. The efficiency varied from 85 per cent in small sets to 98 per cent in large sizes, such as used for traction generating stations; the weight was between 35 pounds and 22 pounds per kilowatt output continuous rating, according to speed and other circumstances; while the steam consumption in 7,500-kilowatt sizes, running at 750 revolutions per minute, with 160 pounds steam pressure at the stop valve, 150 deg. superheat, and exhausting into 27½-inch vacuum, was only 13.5 pounds to 14 pounds per kilowatt-hour, including the steam which is used for auxiliaries.

As regards the induction motor, its powerful starting torque, light weight, simplicity, low cost of construction, mechanical strength, durability, and running characteristics, made it especially suitable for marine work. As there was no commutator and no sparking limit the output could be carried much higher per unit weight than in other machines. These motors could be built for marine work of from 1,000 to 10,000 horse-power continuous rating, weighing 35 pounds to 20 pounds per brake horse-power, with an efficiency of 93 to 97 per cent. Although polyphase motors were termed non-synchronous they always tended toward synchronism, and with squirrel-cage rotors the variation in speed from light to full load seldom exceeded 5 per cent, even in small sizes, and would probably not exceed 1 per cent in large sizes. The main working current passed through the stationary part of the motor only, facilitating strong and reliable construction for the conductors and rendering the machine so simple as to require no skilled and very little unskilled attention with consequent low cost of maintenance.

Assuming a vessel of 4,000 horse-power fitted for electric propulsion with four propellers taking 1,000 horse-power each at 250 revolutions per minute, the motors would be polyphase induction type with squirrel-cage rotors and with stators wound for full, half, and quarter speeds. The generating plant would comprise duplicate sets of turbo-alternators and exciters capable together of supplying 3,250 kilowatts, and running at 1,500 revolutions per minute, with 150 pounds steam pressure and 150 deg. F. superheat. These alternators would be two-pole machines, and the motors would be wound for 12 poles giving a reduction of 6 to 1. For half-speed a second winding would be arranged for 24 poles, giving 12 to 1 reduction with two sets of windings in parallel, and for quarter speed this winding would be arranged for 48 poles, giving 24 to 1 reduction; the synchronous speeds would thus be 250 revolutions per minute for full speed, 125 revolutions per minute for half speed, and 62½ revolutions per minute for quarter speed.

At full speed of the vessel the propellers would require 4,000 shaft horse-power, and the turbo-generators would be run in parallel delivering 3,250 kilowatts to the motors. The consumption of steam would be 13 pounds per shaft horse-power or 16 pounds per kilowatt hour, equivalent to a total consumption of 52,000 pounds of steam per hour. Compared with propeller turbines the consumption in which, under similar conditions and speed, was of the order of 22 pounds of steam per shaft horse-power or a total of 88,000 pounds per hour for 4,000 horse-power, the saving in favor of electric transmission was no less than 41 per cent. At half speed of the vessel about 600 shaft horse-power would be required, less than half load on one turbo-generator, and this would allow the duplicate set to be shut down. Estimating the motors at 60 per cent efficiency on half speed the generator would deliver 740 kilowatts at its full normal speed, and take 24 pounds of steam per kilowatt hour, equivalent to 17,760 pounds per hour, as against 28,200 pounds for propeller turbines, thus saving at least 37 per cent in steam when the vessel is moving at half speed. The weights of the electrical transmission plant in this example would be:

	Tons.
4,000 B.H.P. at 35 lbs. per H.P. developed ..... say	62½
Conductors, switch-gear, etc..... say	6
Two turbo-generators as above..... say	70
Condenser for above..... say	19
Steam piping, etc. ..... say	13
Air pump and motor..... say	6
Circulating pump and motor..... say	7½
	184

While the weight of the direct-coupled turbines and part of the propeller shafts, tunnels, etc., including condenser, steam pipes, etc., air and circulating pumps —which would have to be arranged efficiently to deal with the 88,000 pounds of steam—would be at least, taking the speed of the turbines at 250 revolutions per minute, 148 tons, showing that the electrical machinery would be about 25 per cent heavier, but it is here necessary to point out that that only applies to the plant from stop valve to propeller shaft connections.

This comparison does not cover the saving in power and weight of boilers. On the other side of the stop valve the weight of cylindrical boilers (empty), mountings, funnel, forced draft gear, pipe work for steam-water and exhaust, pumps, gratings, platforms, etc., is stated to be 180 pounds per indicated horse-power in reciprocating engined ships. Taking a vessel carrying two reciprocating condensing engines developing together 4,000 brake horse-power—equal to 4,700 indicated horse-power at 85 per cent mechanical efficiency —the weight of boiler and stokehold equipment would be 377 tons. At 16 pounds of steam per indicated horse-power, including auxiliaries and losses, the total consumption would be 75,200 pounds, or 200 pounds of steam per hour per ton of boiler-room equipment.

At this rate the boiler-room equipment on the electrically equipped vessel, taking 52,000 pounds of steam, would be 260 tons, while for the propeller-turbine vessel the weight would be no less than 440 tons. There would thus be a saving for equal propeller horse-power of 180 tons weight—that is, no less than 40 per cent. Comparing coal consumption, the author took it that, with good Welsh coal, hot feed, and clean flues, it was possible to evaporate 10 pounds of water per pound of coal burned, and at this rate a turbine-propeller vessel would burn 8,800 pounds per hour, as against 5,200 pounds by the electric-propeller vessel—a saving of 1.8 tons per hour. This represented a saving in dead weight carried of about 230 tons on a six days' trip, with correspondingly reduced running cost. Electrical propulsion should be of considerable interest to cargo vessel owners, as not only could dead weight and coal be saved, but the propeller speed could be kept as low as necessary and usual in these slow boats to secure the best economy at the propeller; and it would also be possible further to reduce the propeller speed if necessary to meet practical conditions by slight increase in the weight of the motors only, the generating plant weight remaining the same. The author pointed out that the conclusions deduced should not be considered as perfectly definite, on account of the widely different conditions in practice; but the paper was chiefly put forward to lead naval architects and marine engineers to give serious consideration to the question of electric propulsion.

Reference was made to other systems proposed, and a large number of lantern views and drawings exhibited. The original Hart-Durtnall continuous-current system employed series-wound generators and motors direct-coupled to six propeller shafts, but was for small powers only. In Mr. Parsons's system the exhaust was taken from the main reciprocating engines to drive a low-pressure turbine coupled to an electric generator delivering current to a motor on the engine propeller shaft. Single-phase commutator motors had been proposed in one German and one American system; in the former case with three-phase, and in the latter with single-phase generation, and in one other American proposition three-phase non-synchronous generation was included. A Swiss proposition was to use direct-coupled turbines at the vessel's full speed and a separate turbine driving an electric generator supplying current to electric motors on the main turbine shafts for reducing the vessel's speed or reversing. The reverse, however, in most of these systems was only one-third of full power. The Hart-Durtnall three-phase system, as applied to marine propulsion in conjunction with internal combustion engines, providing a reverse and three ahead speeds with control from the bridge, was referred to, but the author pointed out that until a satisfactory internal combustion engine of large power was produced, the steam turbine would remain the most simple, light, and efficient prime mover.

The Lift of Aeroplanes.—Draw a right-angled triangle, denoting the base by AC and the vertical height by BC. The angle BAC is then the inclination of the plane to the line of flight in still air, and the height BC corresponds to the pitch of a screw. Suppose we assume BC to be one-fourth of AC, say 1 foot and 4 feet respectively; the plane will then move the air downward 1 foot for every 4 feet of travel. Assume the speed to be 44 feet per second; in one second therefore the air will be moved $44/4 =$ 11 feet. V, the acceleration, therefore equals 11 feet per second. The total quantity of air moved per second is found by taking the sum of the lengths of all the leading edges of the planes. This sum multiplied by the distance moved in one second and by 0.08 and by V will give us the weight of air moved, and this weight multiplied by V and divided by 32 (g) will give the thrust, or lift, in pounds. If $S =$ speed per second in feet on the line of flight, P the pitch $= AC/BC$ and V the acceleration $= S/P$, and $L =$ length of the leading edges, we may write the formula as $0.08\,L\,S\,V^2/32 =$ the lift in pounds. In Farman's case the speed S was 45 feet per second, L equaled about 96 feet—we do not know what V was, but assume it to be 10 feet—we get lift or thrust, $T = 96 \times 45 \times 10^2 \times 0.08/32 = 1{,}080$ pounds. It was actually 1,100 or thereabout.—Prof. Rankin Kennedy, in Engineering.

A NEW METHOD IN WET EXCAVATION.

DRAINING INSTEAD OF EMPTYING AN EXCAVATION.

BY C. M. RIPLEY.

"THE Magic City of Steel," Gary, Ind., which represents an expenditure of $75,000,000, has attracted much attention in the world of engineering, because of the magnitude of the work, the speed of construction, and the methods adopted. With a population of fifteen thousand, Gary is scarcely two years old, yet it has about ten miles of paved streets, twenty miles of gas mains, an electric light plant, full telegraph and telephone service (both long-distance and local), and a new elaborate system of sewers about twenty miles in length rapidly nearing completion. The sewer system is to cost $350,000, and about half of the contract was awarded to Green & Sons, contractors, of Chicago, Ill.

This article deals with the methods and costs of the contractor in overcoming the difficulties of quicksand, which will flow in from a radius of fifteen feet if an excavation be dug one foot in depth and left unconfined. The sand when dry is so impalpable that it is ankle deep. So low is the land also, with reference to Lake Michigan, that in many places there are surface ponds three and four feet in depth.

In designating the arrangement of the apparatus, the "front" or "foremost" end of the sewer trench will be that end at which the excavation is being carried on, and the words "first," "second," and "third" pumps will serve to indicate their relative position with reference to the front end of the sewer trench.

It will be seen from the illustration that the first vacuum pump has had to drain the excavation immediately adjacent to the scraper bucket excavator. The suction pipe is connected with a horizontal 4-inch header as shown. The 2-inch well points are 3 feet long and are connected at the end of 2-inch pipes 13 feet long and jetted 2 feet apart, in a double row near the center of the trench. This arrangement is made so as to allow the sheeting to be driven on either side. Thus, pump No. 1 draws its water from:

132 2-inch well points sunk 16 feet below water level.

1 4-inch well point sunk 16 feet below water level.

1 4-inch suction pipe with a strainer placed on the "front" end of the horizontal header and draining surface water.

The 4-inch horizontal header mentioned in connection with pump No. 1 is made up of six sections each 22 feet long and joined by flanges. As the work progresses 22 feet, the rear section is removed and placed in front and so on. Gate valves at frequent intervals make it possible to do this without shutting down. Thus the pump can remain in one position even though the excavation progresses some 100 feet.

The vertical pipes leading down to the well points have ells at the top and a 4-foot length of hard wire-lined rubber suction hose makes the connection to the main header. Each 22-foot length of this main header has eleven cross valves each with two bushings, and each bushing accommodates one two-inch hose and sucks water from one well point.

After the draining has been carried on for an hour or so in the first of the six sections of the horizontal header, on either side of the sixth section 2 x 8 x 12 foot wooden sheeting is driven with mauls. Then excavation is started by shovelers, and is carried down about 6 feet more. It is at this level that the well points attached to the second and third pumps are sunk to another 16-foot depth, so that they penetrate below the bottom of the lowest excavation and 6 feet below the lower edge of the sheeting. Thus the total depth of the trench is made up of the following stages:

8 feet down to water level by bucket excavator,

6 feet near pump 1 by shovelers, and

16 feet under pumps No. 2 and No. 3, also by shovelers.

This entire excavation is in comparatively dry sand, and would stand at ½ to 1, although the same sand when wet would not stand better than 15 to 1.

The second and third pumps have their suction pipes as the electrical engineer would say, "Operating in parallel"; that is, they are both drawing water from the same piping system. The two pumps are both drawing water from:

One 4-inch suction hose straight down from pump,

One 4-inch rubber hose leading to right, and

One 4-inch suction hose leading to left.

This arrangement is effected by means of a four-way connection in the suction of each pump and about 1 foot below it. The two 4-inch rubber hose leading horizontally from the four-way connection and at right angles to the trench are only long enough to connect through tees with 2-inch headers, also horizontal, which extend along the sides of the trench just inside the sheeting. It is to these headers, one on either side of the trench, that the 1¼-inch well points are connected and jetted down as close as possible to the sheeting, so that the shovelers can work inside these vertical drain pipes without hindrance.

Here again gate valves at frequent intervals allow of considerable flexibility, so that lengths can be shifted from rear to front as the digging progresses. Another and most ingenious arrangement is that the pumping can be made stronger in any part of the excavation where specially large quantities of water may be encountered. Thus the entire combined capacities of both pumps No. 2 and No. 3 can be concentrated on those well points in the wettest part of the work, by closing the gate valves and shutting off the vacuum from other parts of the trench pipe line. This arrangement would of course be impossible if an ordinary "sump" were used, for as the progress of the work demanded it, new sumps would have to be dug and braced and other pumps hung at considerable total

BIRD'S EYE VIEW OF GARY SEWER.

Showing inrush of surface water and fluid sand, pumping plant, trench, clamshell putting in backfill, and new steel mills in the far distance.

expense for labor and materials. The idea of "distributed" suction, as used at Gary, makes the pumping more efficient than the old "sump" method, because the water is drained only from the exact location of the excavation, instead of from a circular area mostly outside the limits of the trench, being all water from within a certain radius.

Two men were timed while using a 1-inch water-pipe for jetting down the 1¼-inch well points used in connection with the second and third pumps. The jetting stream was supplied at 100 pounds pressure, and the two men sank four well points in one minute. This time does not of course include the making of rubber connections with horizontal headers.

It is a fact worthy of note that the hundreds of connections between flanges, rubber hose, ells, and suction pipes cannot be made absolutely air tight and that, with the high vacuum inside, a considerable amount of air must find its way into the suction of the pumps. This fact does not seem to hinder their operation, owing probably to the large volume of the chambers in which the condensed steam forms the vacuum.

It is interesting to contrast this vacuum method with its diametrically opposite method—the pneumatic caisson process or compressed-air method of excavating in water-bearing strata. The pneumatic process uses compressed air to force the water downward, away from the sand or other soil to be excavated. This excavation can frequently be carried down below the edges of the caisson.

So also in the vacuum method at Gary, the digging is carried down below the bottom of the wooden sheeting, and this in very fluid material, showing that draining the water from below is as effective in the Gary method as is the displacing of the water from above—the compressed-air method. Obviously, the expense of air compressors and air locks, and the dangers of air pressure to the workmen, are far beyond the small investment required for pumps and pipes.

The discharge pipes of the first three pumps empty into a 10-inch tile drain laid in a small trench by the side of the main excavation. This in turn discharges into the completed sewer on the far side of a dam of sandbags. The amount of water so discharged has not been accurately measured, but it is a rushing stream two-thirds filling the 10-inch drain pipe, and flowing at a rapid rate, owing to a drop of over 20 feet in 200 feet.

The backwater in the completed sewer is about 4 feet deep, and the seepage through this dam, as well as that which leaks in through other channels, is sufficient to keep a fourth vacuum pump working continuously day and night. A temporary manhole was built in the center of the arch, and in this was suspended a fourth Emerson pump known as the No. 1 size, with a 3-inch suction and 2½-inch discharge pipe, and a capacity of about 250 gallons per minute.

The Strength of Chain Links.—A series of experiments on chain links and circular rings, covering a period of two years, has been recently completed at the Engineering Experiment Station of the University of Illinois by G. A. Goodenough, associate professor of mechanical engineering, University of Illinois, and L. E. Moore, assistant professor of civil engineering, Massachusetts Institute of Technology, formerly instructor at Urbana. The work was undertaken for the purpose of confirming or disproving a theoretical analysis of the stresses in links and rings. A comparison of calculated and measured deflections afforded the desired test, and the results of the investigation abundantly confirmed the analysis. A reliable theory having been derived, the bending moments and maximum stresses were calculated for links of various forms, and the results of such calculations were applied to the formulas for the loading of chains given by Unwin, Bach, and Weisbach. These latter are of the form $P = kd^2$, where P is the load in pounds, d the diameter of the link in inches, and k a constant varying from 11,000 to 18,000. In the formulas given by these authorities, however, the maximum stress to which the link is subjected seems to be under-estimated, the values of k being such as to give maximum tensile stresses of from 33,000 to 40,000 pounds per square inch, and maximum compressive stresses of about 60,000 pounds per square inch. The formulas arrived at by the authors are:

$$P = 0.4d^2S, \text{ for open links, and}$$
$$P = 0.5d^2S, \text{ for stud links,}$$

where S denotes the maximum permissible tensile stress in pounds per square inch. If S is taken at 15,000, the corresponding values in the earlier formula for k are 6,000 and 7,500, respectively, for open and stud links. The investigation is described at length in a 72-page bulletin (No. 18) published by the university, and the theoretical discussion which was the basis of the experimental work is given in full in appendices. Copies of the bulletin may be obtained upon application to the Director, Experimental Station, Urbana, Ill.

In the Atlantic Monthly Mr. J. O. Fagan makes some interesting comparisons between British and American railroads. He shows that in the year 1906 a total of 1,200,000,000 passengers were carried on British railways on 27,000 miles of track, against 800,000,000 passengers carried on American railways on a mileage of 200,000. As regards accidents the same writer says that if we take the year 1906 we find that there were 13,455 collisions and derailments in the United States, and only 239 in Great Britain. In the same year 146 passengers were killed and 6,000 injured in the United States, against 58 passengers killed and 631 injured in Great Britain. The number of employes killed and injured in train accidents was respectively 13 and 140 in Great Britain, against 879 and 7,483 in the United States.

NEW FORMS OF STEEL FOR NEW USES.

STRUCTURAL SHAPES RENDERED NECESSARY BY THE STEEL BUILDING.

BY R. B. WOODWORTH.

Concluded from Supplement No. 1702, page 102.

SYMMETRICAL INTERLOCK.

MR. FARGO in his patent claims only an improvement on the Friestedt form of steel piling. Mr. Fargo's own piling, however, is subject to the disadvantage that in driving there is nothing to hold alternate sections in alignment except the pressure of the material and the friction in the pile-driver leads. Consequently there has been devised a further improvement called the symmetrical interlock, which consists in riveting a single zee bar full length on each section at one edge, with a short piece at the other edge at the top only of each member, the function of the short clip piece being only to hold the material in alignment, and to distribute the blow of the pile-driver more uniformly over the section than is done in the Fargo type.

The success of Friestedt interlocking channel bar piling has incited Mr. James J. Harold to work up a wooden composite type of piling based on the use of standard channels in which the zee bars are omitted and the channels held together by short bars, overlapping the interlocking flanges and bolted to wooden timbers, making a solid steel and wood wall. This form of composite piling is shown by patents 808,838 of January 2, 1906, and 820,304 of March 8, 1906.

INTERLOCKING DOUBLE CHANNEL BAR.

Mr. George E. Nye has exercised his inventive genius further on interlocking channel bar piling with the result that in patents 832,407 of October 2, 1906, 850,043 and 850,044 of April 9, 1907, he has developed what might be called interlocking double channel bar piling. This form might be successful under heavy driving conditions but is too heavy for ordinary use and patents 850,043 and 850,044 require special rolled shapes for their manufacture, thus entailing additional expense over the other forms.

INTERLOCKING ZEE BAR.

The success of the interlocking channel bar piling called forth interlocking zee bar piling, represented in patent 725,608 granted to Henry Wittekind, of Chicago, on April 14, 1903. The Wittekind piling does not seem to have received any particular attention from the engineering profession and is rather too complicated for ordinary uses.

DOUBLE TEE INTERLOCK.

Mr. George E. Nye has also patented what might be called the double tee interlock form of steel piling which is represented in patents 753,094 of February 23, 1904; 778,601 of December 27, 1904, and 816,994 of April 3, 1906, all of which are owned by Mr. L. P. Friestedt and which require the manufacture of special rolled shapes before any fabrication can be done.

INTERLOCKING TROUGH PLATE.

It will appear from this discussion as though we had invented sufficient forms of steel piling for all practical purposes, but in addition to rolling shapes, structural mills also roll plates which can be fabricated into various forms and we have the next form of steel piling which may be called the interlocking trough plate type, and consists essentially of the use of trough plates or similar forms in steel piling construction.

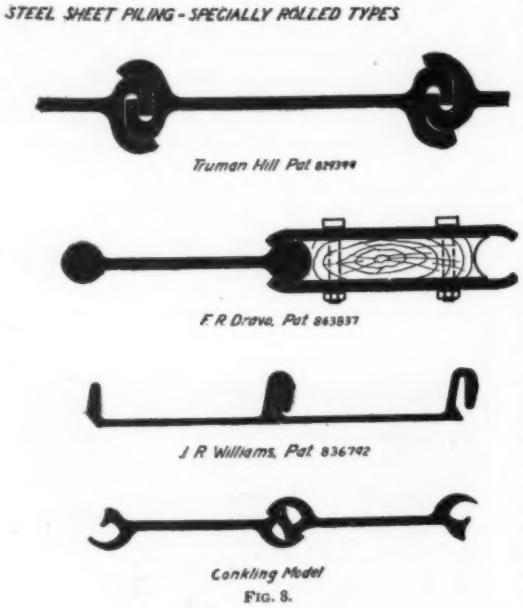

STEEL SHEET PILING - SPECIALLY ROLLED TYPES
Truman Hill Pat 819799
F.R Drave. Pat 863837
J.R Williams. Pat 836792
Conkling Model

FIG. 8.

Any form of this type of piling would give a large radius of gyration and a corresponding high efficiency of strength. They are, however, difficult to fabricate and are based on a high-priced class of material to begin with. The first patent based on the use of trough plates was granted to Frank N. Kneas, of Chicago, No. 744,361, on November 17, 1903. This was followed by patent 751,469, February 9, 1904, granted to Walter L. Cowles and James N. Hatch, of Chicago, Ill. The ideas of these inventions have been extended and improved upon in patent 801,946 of October 17, 1905, granted to Julius R. Wemlinger, of New York. No form of interlocking trough plate piling has yet been fabricated or driven, and the Wemlinger piling in its latest form calls for very expensive rolling processes to produce the necessary plain sections.

BOX INTERLOCK, ETC.

The use of plates for sheet piling has been a fertile idea in the minds of inventors. George W. Jackson's patent 697,943 of April 15, 1902, shows what might be called the box interlock in which the ends of the plate are bent around into a box form to make an interlock. Patent 824,513, of June 26, 1906, granted to R. H. Stevens, Homestead Steel Works, represents what may be called the *scroll interlock*, in which the complete pile has an end section like the scroll of the engraver, with the exception that one end is of smaller radius of curvature than the other. Lester R. Gifford and R. V. Sage, of Westmont, Pa., took out patents 766,131, 766,132 and 766,147, all dated November 2, 1904, on *corrugated interlock*, in which the sheets themselves are corrugated as in roofing and the interlock is formed by a special rolled shape fitting closely over the apex of adjoining sheets.

SPRING LOCK STEEL PILING.

Steel plate piling, however, finds probably its best representation in the spring lock steel piling, on which patents 842,120 of June 22, 1907, 843,307, of February 5, 1907, and 863,886, of August 20, 1907, were granted to Frank W. Skinner, of New York city, and in which the essential idea is to provide adjoining plates with their ends curved to slightly different radii which in driving compels the sheets to lock closely to each other. The same idea is represented in patent 838,152 of December 11, 1906, granted to John R. Williams, of East Orange, N. J. So far as information goes, no form of plate piling has yet been driven in the United States. The use of plates commends itself to the inventor for the reason that it is possible to get material of different thicknesses and weights to correspond to almost any theoretical constructions. The great difficulty with plate piling, however, is that there is required in connection with the piling itself some form of mechanical device in the way of a follower to go down with the sheets and to hold them in position until bracing can be done, and it is very apparent that the use of these followers, as is necessary with each sheet, calls for not only increased expenditure, but delay in the driving itself. There is a very interesting form of plate piling known as the *camber plate piling*, which has had considerable use in Germany and has been discussed in a general way in England, full particulars of which may be found in the Transactions of the Junior Institution of Engineers, March, 1907, in an article entitled "Timbering of Excavations." This form was invented by Mr. F. Lang, of Hamburg, and it has been employed at Hanover for the extensive coffer-dam foundation of the Provincial Revenue Offices, and consists of bending vertical edges in specially constructed machines to form a labyrinth U-joint. The plates themselves are bent to a radius of 27 inches, which gives a camber of 2¾ inches in each sheet. This form, however, seems to be too cumbersome to meet that simplicity and economy which is required by the engineering and contracting ideals of America.

ROLLED SECTION.

This exhausts the consideration of the fabricated

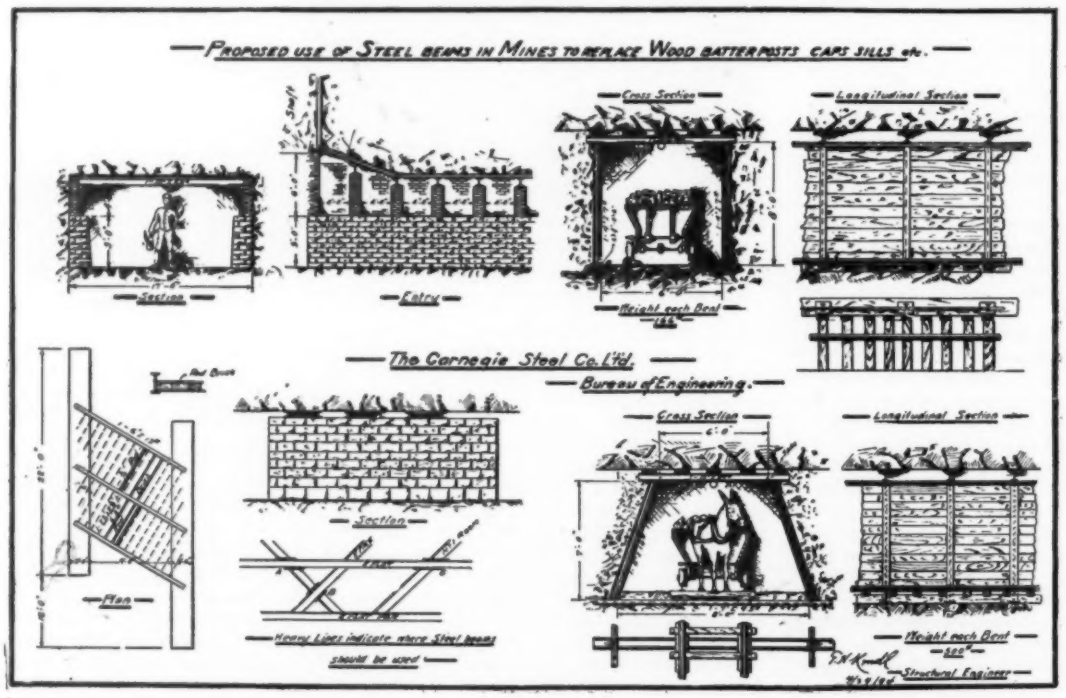
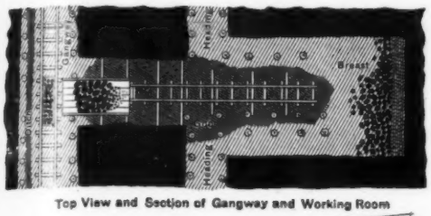


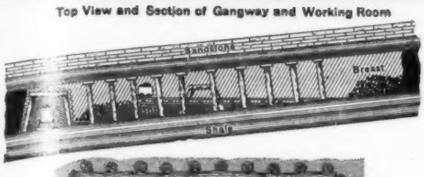
FIG. 9.

* Read before the Engineers' Society of Western Pennsylvania.

forms of steel piling. It is apparent to everyone that the ideal steel piling should be complete in itself; that it should be simple; that it should interlock perfectly and that each adjoining piece should have the same theoretical strength. Consequently the ideal form of steel piling should be a rolled section and patents have been granted along this line of various value. The first United States patent showing a rolled section was 103,028, dated May 17, 1870, and granted to Lewis Dodge, of Chicago, for improvements in the construction of tunnels and dams. This patent shows two



Top View and Section of Gangway and Working Room



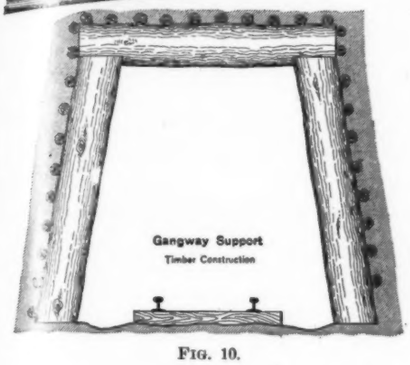
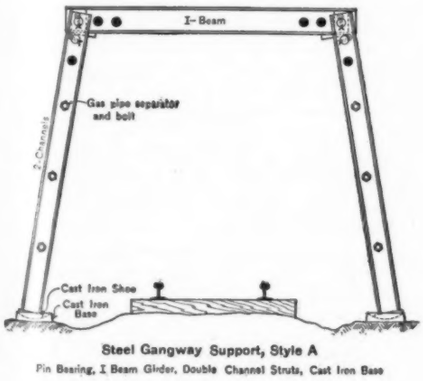


FIG. 10.

forms the ball and socket form with the head of one piece fitting into the socket of the other, and the rectangular form in which the connections were made by dovetailing. It is also interesting to note that Mr. Dodge contemplated the use of his section for tunnel lining rather than for sheet piling purposes, an indication of what has often happened in the use of new material which has advantages, that those who built, built better than they knew and that really valuable ideas are developed and extended and improved upon and used for different purposes by the generations that succeed their originators.

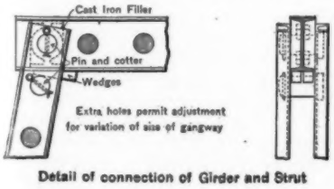
NOVEL IDEAS IN ROLL TURNING.

Practically 65 per cent of the piling sold to-day is shown by patent 639,884 granted to Samuel K. Behrend, of Washington, on December 26, 1899, and is known commercially as United States steel sheet piling. This piling incorporated the idea advanced by Lewis Dodge, but improved upon by making the section more ideal and by the introduction of packing strips to provide for that water-tightness which is necessary in submarine construction. The manufacture of this form of steel piling has also brought forth novel ideas in roll turning. Mr. Walter C. Harder was granted on October 4, 1904, patent 771,426 in which the essential idea was to form an interlocking member by turning over a beam flange so as to form an interlocking curve. Immediately on the issuance of this patent, its infringement with the Behrend patent was noted. The matter was taken into court and in the court room it was testified that steel piling covered by the Behrend patent could not be rolled by any method known to the art. In spite of this, the Behrend piling was rolled successfully on December 23, 1904, and it was rolled by the special method of rolling invented by Edwin E. Slick and covered by patent 852,984 granted May 7, 1907. It is this Slick method of rolling which has made possible the development and success of the United States steel sheet piling.



Steel Gangway Support, Style A

Pin Bearing, I Beam Girder, Double Channel Struts, Cast Iron Base



Detail of connection of Girder and Strut

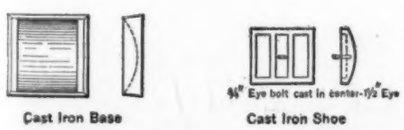


FIG. 11.

VANDERKLOOT PILING.

This success has called forth competition, and Mathias R. Vanderkloot, of Chicago, has taken out patents 763,526 of June 28, 1904, and 786,329 of April 4, 1905, covering a form of rolled section in which an interlock is formed by bending over into hooks the flanges of what starts through the mill as an unsymmetrical beam section. The form of the Vanderkloot piling as actually rolled represents quite a departure from that shown in his patent, which is only an illustration of the fact that successful invention must go hand in hand with practical rolling mill experience.

Patent 778,354 of December 27, 1904, granted to Rudolph Dobry, represents a form of piling in which the interlock is made by unique dove-tailing. It is needless to say that this form of piling is out of the question from a rolling mill standpoint. The same criticism applies to George E. Nye's patent 782,872, February 21, 1905, also the very ingenious but far-fetched idea represented in patent 826,801, July 24, 1906, granted to C. H. Quimby, Jr., of Pittsburg; also to another unique dove-tailed form of steel piling covered by patent 829,596, granted to J. J. Nolty, of Canal Dover, O., August 28, 1906.

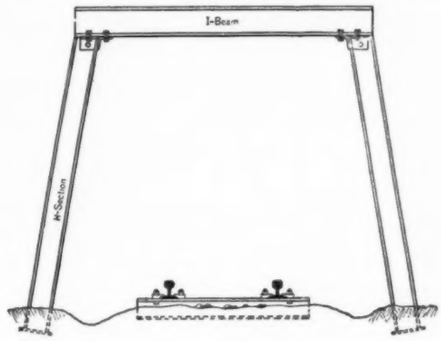
The Vanderkloot ideas have been followed by Truman Hill, of Chicago, in patent 829,399, of August 28, 1906, in which the interlock is similar to the construction of the modern coupler attachment of standard freight cars.

We are not dealing here especially with composite wooden piling, but reference should be made in this connection to patent 863,837 of August 20, 1907, granted to Francis R. Dravo, of Sewickley, Pa., which represents the ideas of a substructure contractor who has had large experience in driving steel piling himself. It is based on the use of two special rolled steel shapes and wooden fillers in which interlocking means are provided and ample attention paid to the requirements of water-tightness.

Numerous as these piling patents are, the inventors of steel piling have gone so far as to provide special means for driving and for pulling in order to facilitate the installation of the piling itself, and which are really necessary when material is to be drawn and re-used so as to prevent battering of the piling head and closing of the interlock. They have also patented the use of the piling itself. For example, patent 762,042 granted to L. P. Friestedt June 7, 1904, covers by means of steel piling a method of raising subterranean rivers so as to make underground water available for purposes of irrigation. Patent 832,371 granted October 2, 1906, to the same party covers the construction of ship canals, with special reference to the St. Clair Flats, while patent 832,964 of October 9, 1906, deals with the application of steel piling in the construction of building foundations and retaining walls.

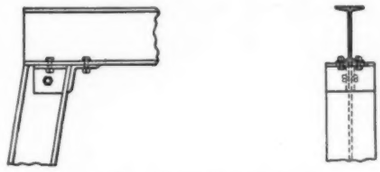
USES OF STEEL PILING.

Having described various forms of steel piling now on the market, some of which have distinctive merits and some of which are absolutely without value, we will proceed to consider their uses. Steel sheet piling in general can be used for any purpose for which wooden sheet piling can be used, and its first and most common use is in the construction of cofferdams for building bridges. It is for this purpose that the largest sales of steel sheet piling have been made. Its repeated use in such work has called forth entire satisfaction from its users, its large advantage and great economy consisting in the ease with which it can be driven and the ability to withdraw and re-use over and over again, without serious injury. The cofferdam for the new bridge now being built by the Chicago & Northwestern Railroad across the Mississippi River at Clinton, Iowa, for example, has required about 1,166 tons of 40-pound United States steel sheet piling. There are nine cofferdams to be constructed and steel piling will be used three times. The piling is being driven with a 3,200-pound drop hammer falling approximately 15 feet. Packing strips were not used. There were leaks present in the piling, but not of sufficient size to interrupt the work. In order to rush the work on this job, the C. & N. W. people used a double wall of steel piling with puddle. They admit, however, that with a single wall of piling, using

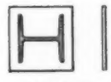


Steel Gangway Support, Style F

I-Beam Girder H-Section Struts, Steel Cap and Base



Detail of Connection of Girder and Strut

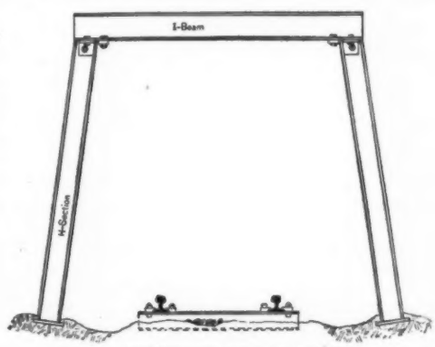


Base Plate

FIG. 12.

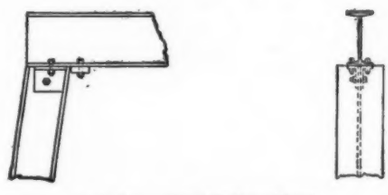
the wooden strips, they would have had practically a watertight dam. Six to thirty piles were driven each working day at a cost of 18 cents per lineal foot of structure.

The National Tube Company, in carrying out improvements at its Pennsylvania department, McKeesport, built in 1907 a concrete river wall 1,660 feet long. One end of this wall is entirely in the Monongahela River, and the wall runs along the river bank in a direction inclined thereto, so that the other end is in dry ground, the space between the wall and the bank being eventually filled in. This wall was constructed in four installations of three cofferdams each, the piling being driven with a 3,600-pound drop hammer, pulled and used over again, sufficient piling being purchased for one installation only. Thirty-five pound

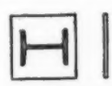


Steel Gangway Support, Style C

I-Beam Girder, H-Section Struts, Steel Cap and Base



Detail of Connection of Girder and Strut

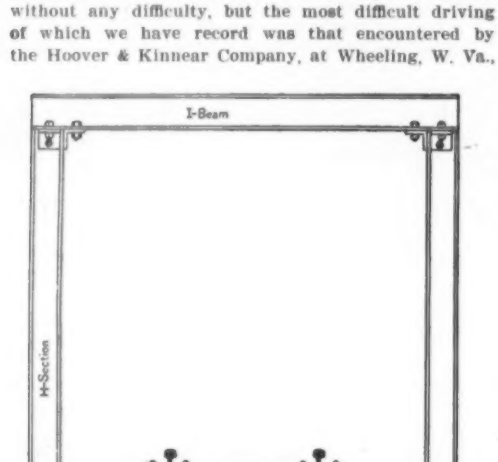


Base Plate

FIG. 13.

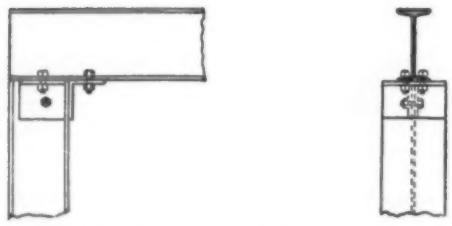
United States steel sheet piling was used without calking beyond the silt and mud found in the river bottom. There were no leaks present of a size sufficient to interrupt the work, which was entirely satisfactory in every respect.

The Marsh Bridge Company have recently built a cofferdam for a bridge pier at Peoria, Illinois, using 130 tons of Friestedt 15-inch 38-pound. This material was bought second-hand from the Cullen-Friestedt Company, who had used it for two cofferdams previously. The Marsh Bridge Company have driven it fully three times, making five times in all that the same set of steel piling has been used. Bayne & Hewett, contractors, Minneapolis, Minn., used 15-inch 38-pound Friestedt piling in cofferdams for the government bridge at Rock Island. They installed the same lot of piling four times, driving it down through 17 feet of sand, gravel and hardpan. No method of caulking was used and yet the leakage interfered at no time with the progress of the work and the cost of driving amounted to only 14½ cents per lineal foot of substructure. Steel piling in use has met, of course, with all sorts of obstructions. It has successfully penetrated in one case three 16-inch square timbers without any difficulty, but the most difficult driving of which we have record was that encountered by the Hoover & Kinnear Company, at Wheeling, W. Va.,

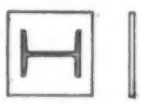


Steel Gangway Support, Style H

I Beam Girder, H-Section Struts, Steel Cap and Base



Detail of Connection of Girder and Strut



Base Plate

FIG 14.

in constructing a cofferdam for the Baltimore & Ohio Railroad bridge. Here the material encountered all kinds of difficulties. It was even attempted to drive the stuff through a locomotive axle which happened to be in the debris on the river bank, and while the piling was seriously bent and twisted, and re-drawing was extremely difficult, it was finally accomplished and the second installation proceeded with. In this connection the experience of the Norfolk & Western Railway is instructive. In changing the alignment of their bridge over Paint Creek, near Chillicothe, it was necessary to rebuild the structure which had stood for about twenty years, and absolute comparison between wood and steel became possible, the piers built with wooden cofferdams on the old bridge being only about 250 feet from the new ones.

RELATIVE COST OF STEEL AND WOOD.

Twenty years ago the contract cost per structure of several curtain wood cofferdams was $452.50. At the present time the same wood structure would cost $638.22. United States steel piling was used five times for five cofferdams within 300 feet of those twenty years ago and came out of the work practically as good as new. Make your own analysis. Apply any method of figuring and the economy of U. S. steel piling will be strikingly apparent. For instance, after a five-fold use U. S. steel piling was practically as good as new. Making no allowance for salvage or scrap value, the cost per structure was $505.09, with piling on hand as good as new. Charge depreciation, on account of a final or scrap value, of from 30 to 35 per cent, and in view of the good condition of piling after using five times, it is hardly reasonable to charge off 10 per cent of the total cost of piling against each of five cofferdams, 41 per cent in all. But even on that basis, the cost per structure would be $289.95 and the piling would be on hand as good as new, possessing a salvage value of 59 per cent, equal to $1,075.68, or a scrap value of say 30 per cent, equal to $546.50. Credit a scrap value, $546.50, *pro rata* to five cofferdams charged at $505.09 each and the net cost per structure would be $395.79; or credit a salvage value $1,075.68 *pro rata* to five cofferdams charged at $505.09 each and the net cost per structure would be $289.95. The saving on steel piling on any calculation is apparent.

USE IN RETAINING WALLS, SEWER AND TRENCH WORK.

Steel sheet piling has also been used extensively in the construction of retaining walls, sewer and trench work, and foundations of all kinds. In these instances it takes primarily the place formerly occupied by wood. There are other instances, however, in which steel sheet piling has been used where wooden sheet piling could not be used to an advantage. It has been used by the United States Reclamation Service in the driving of curtain walls to resist underground percolation of water, and has in this way effected a great saving in the reduction of excavations otherwise necessary and in the time consumed in the construction. Along the same lines is its use by the engineering department of the United States government in the protection of the wooden dams in the Allegheny River. During the freshets of the early part of 1907, the wooden dams became undermined and it was also necessary to use dynamite to dislodge the ice gorges which had accumulated beyond them. Also the banks at Springdale with the buildings thereon erected were eroded and swept away by the force of the current. In reconstruction of these dams, and in order to economize where possible, the United States government decided to drive 40-foot United States steel piling along the entire upstream face of the dams and along the wing walls. This will most effectively prevent any underscouring action of the water and will make the structure practically perfect.

USE IN DAMS.

In line with this use in streams to prevent underscour, is its use in the construction of dams for hydro-electric projects. The dam of Grand Rapids-Muskegon Power Company, Grand Rapids, Mich., is an illustration of what can be done in this direction, and the same company who years ago constructed that dam, built this year a dam for the Berrien Springs Power Company, at Berrien Springs, Mich. Under previous methods of operation in building a dam across a valley, it would have been necessary to excavate far below the surface of the ground and to construct a masonry or concrete wall as a core to prevent seepage of water below the dam itself. All the expense and delay incurred by this practice have been avoided by the use of steel sheet piling which is driven down to the surface of the ground and the masonry dam built above it.

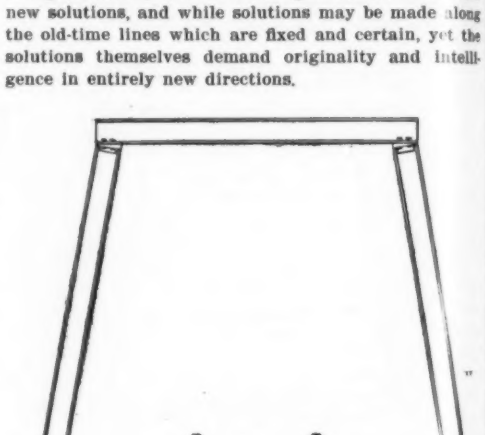
Along this same line also is the intended use by the United States government of steel sheet piling in the construction of a sea wall at Fort St. Philip. Here steel piling will be driven and the tops capped with concrete to form the outline of the wall itself. About 1,450 tons will be used in this construction.

DRIVING—BRACING.

Steel piling can be driven with any of the ordinary forms of wooden pile drivers. The weight of driving hammers and general equipment will, of course, depend upon conditions of driving, character of soil, length of material and personal prejudices of the contractor. Ordinarily it can be pulled with the same tackle with which it is driven, though, like any other class of structural material, its use must be attended by skill and intelligence. There is a question of engineering interest in this connection which has not yet met with a satisfactory solution. This is the whole question of bracing. We do not know just what reactions are to be met with due to earth pressure, nor in general how earth pressure acts. The December Proceedings of the American Society of Civil Engineers contains, for example, a long discussion on this subject, which is marked mainly by the difference of opinion of those who took part therein. It appears reasonable to suppose that bracing may be made lighter as the depth of the installation increases, and yet any theory, based on the homogeneous character of the soil, will be vitiated just as soon as either hardpan or quicksand is encountered. The whole question at present is a matter of experience and judgment. It is better to put our trust in strong bracing beams than to take chances of serious failure, not that the piling would be destroyed by almost any conceivable failure, but because of the delays and expenditure incident thereto, due to lack of judgment in preparing the bracing. We have in mind the failure of a cofferdam not very far from Pittsburg where the contractor left the steel piling with an unsupported length of 14 feet subject to earth and water pressure. It is entirely probable that a single additional line of bracing at small expense would have made the cofferdam absolutely safe. Any engineering materials, however perfect, must be used with engineering intelligence. So used, steel sheet piling commends itself as the perfect modern material of construction.

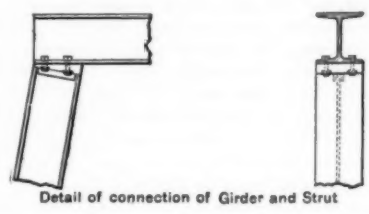
USE OF STEEL IN COAL MINING.

The next item of interest to us in connection with the new uses of steel is its use in substitution for wood in the mining of coal. Here both factors, of which we have already spoken, find place, for the steel, though primarily to take the place of material which is proving more or less harder to obtain and less economical as the years advance, has this additional quality that it serves to prevent to a large extent destructive fires in mining operations, which in the past years have been the cause of loss of life and property. Here again we meet with the truthfulness of a statement made years ago by an old-time writer that "there is nothing new under the sun." However that may be, it is an unquestioned fact that the solution of problems, as they present themselves to different generations, are for those generations concerned new solutions, and while solutions may be made along the old-time lines which are fixed and certain, yet the solutions themselves demand originality and intelligence in entirely new directions.

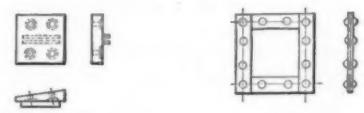


Steel Gangway Support, Style C

H Sections Girder and Struts, Cast Iron Cap, Steel Base



Detail of connection of Girder and Strut



Cast Iron Cap

Base Plate

FIG. 15.

The production of coal mined in the United States has increased by leaps and bounds in every decade of the records. Statistics show the following figures for the United States:

Total tonnage mined in the United States—	Gross Tons.
1816	75
1826	147,914
1836	984,832
1846	4,865,522
1856	13,546,925
1866	29,003,583
1876	53,280,000
1886	113,680,427
1896	191,986,357
1906	414,157,278

Along with this increasing production, which has made the United States the foremost coal producing country in the world, so that in 1906 our country mined 37.43 per cent of the total world production, surpassing even Great Britain in its tremendous output by 47.3 per cent, there has come the rapid exhaustion of such sizes of timber as have been absolutely necessary for the conduct of the mining operations, and the great problem immediately before the coal mining operators is a problem which confronts the very continuance of those operations. The timber resources of our country were once supposed to be practically exhaustless, but when we consider that in 1906 approximately 150,000 acres of forests disappeared down the slopes and shafts of the anthracite regions,

260,000 within the rooms and headings of the bituminous mines, a total of 641 square miles of trees, and more than half the area of the State of Rhode Island, you will note the pertinence of the proposal of steel as the logical successor of wood in coal mining operations. The timber in the mines cannot be looked upon under present conditions in any way as a permanent installation, as the life of timber, especially in the anthracite regions, is so short that the timber requirements must be looked upon by the mine owners as a regular annual fixed charge, and it is conservatively estimated that the entire equipment inside the workings of the anthracite mines in the shape of timber must be replaced in twelve to eighteen months. The Forest Service of the United States Department of Agriculture, as the result of elaborate investigations, have reached the conclusion that in the anthracite region 45 per cent of the destruction of timber is caused by the variations in temperature and moisture and the bacterial organisms, 35 per cent by crush or squeeze, due to the displacement of the strata under mining operations; 10 per cent is destroyed by insects, and 10 per cent wasted.

Preservative treatment of the wood has been recommended to prevent a portion of this annual loss. It is, however, generally recognized that preservative treatment is only a partial solution, and that as a last resort the miners of coal must come to the remedy used in other forms of building construction and use steel for their permanent installations.

The use of steel in mines is not at present to be looked upon in any way as an experiment inasmuch as there have been in use in the past twelve or fifteen years in the mines of the Susquehanna Coal Company steel timbered gangway supports which have been in use in deep parts of the mines exposed to constant contact with mine water and without signs of failure or corrosion.

The first use of steel by the Susquehanna Coal Company marks approximately the time when the mine operators of this country began to realize the importance of making provision for the replacement of wood due to its increasing scarcity and cost. It is also a matter of history that about this same time designs were made in Pittsburg for the replacement of wood by steel in coal mining operations, in connection with which Fig. 9, made by the Carnegie Steel Company on April 24, 1894, will be of interest.

Fig. 10 shows the ordinary form of timber used in mining operations in the State of Pennsylvania. It consists of two round sticks of timber, or legs, supporting another stick of timber called a collar, around which are placed small wooden poles to prevent the falling in of the sides and roofs, and to transmit the load on to the timbers themselves. The size of the timber, like the size of pillars, is not determined by ordinary methods of calculation. It depends upon the depth of cover, the character of the roof, floor and coal, thickness of the seam, the presence of gas or water in the strata, and the general method to be adopted in the moving of coal and drawing the pillars. Under present conditions and without the knowledge which in time will come from the careful tests of steel in actual use, the only method by which to determine the proper size of steel timbers is to compare wood and steel in accordance with their theoretical values.

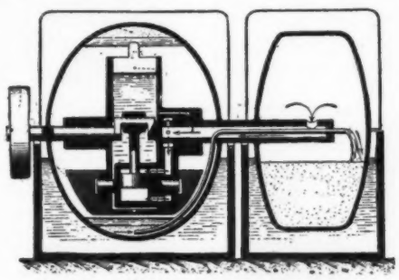
Fig. 11 illustrates that form of construction which was designed by Mr. Norris, in which provision is made for adjustability both at the top and bottom, pin connections being used at the top and rocker castings at the bottom. Steel wedges are driven in at the bottom of the beam so as to distribute the weight on two pins, and additional holes are provided to take up differences in levels. It will be noted that in this form of construction it is necessary to assemble one beam, four fillers, two wedges, four pins and cottars, four channels, four shoe castings, six pieces of cast pipe and six bolts, 31 pieces in all. In ordinary practice beams and channels are bought from the steel makers and castings from a foundry, pins from a structural shop or bridge company, bolts and separators from still other parties, making, as a rule, about four different sets of purchases. This makes the cost of this form of timber comparatively high, and there is needed some form of construction which will be equally strong, but more convenient to manufacture and simpler to erect. It is but fair to say, however, that a large proportion of the steel timber installations now in place have been patterned after this form, and where great strength is required, it will be necessary, and simple as well, to use steel beam collars, framed in between double channel legs, as shown in this arrangement.

Observation and experience, however, indicate that adjustability is not needed in the steel timbers any more than in the wooden timbers whose place they are to take. It is also apparent that the problems of erection can be more fully and satisfactorily met if simplicity is made a large feature of the ideal construction, and for the legs of the square mine timbers and for props it has been apparent for some time that in the United States at least the most economical section has not been rolled. Nature builds the strongest sections in the form of hollow cylinders which have the largest radius of gyration for the least given weight of material, and therefore the greatest strength. Round sections, however, are not simple, and to make connection thereto is difficult and intricate. Therefore, it is necessary to look for as close an approximation to circular form as is possible under present conditions. This is given us in the H section, a form of rolled shape which possesses a large radius of gyration and the most economical distribution of material in comparison to its weight, and which is especially adapted for use in mining operations. The first manufacturer to furnish these in the United States was the Carnegie Steel Company, and its 4, 5, 6, and 8 inch sections, all of which are now successfully rolled, have been designed especially for use in coal mining operations. The 4-inch section weighs 13.6 pounds per lineal foot, the 5-inch 18.7 pounds, the 6-inch 23.8 pounds, and the 8-inch 34.6 pounds, which gives a range of sizes sufficient to take care of all of the ordinary requirements of coal mining operations, and whose simplicity is plainly proven in the types of construction shown in the figures.

Fig. 12 shows perhaps the simplest form of construction adapted for mining purposes. It consists of a beam collar, two H-section lug angles at the top thereof to prevent side motion, and absolutely plain plates for bearing. This form of construction has been successfully applied in the mines of the Midvalley Coal Company, and is specified for 150 sets of the Lytle Coal Company, and 25 sets for the Pine Hill Coal Company, and is believed to represent the ideal form for this purpose. If the bearing plates were omitted, there are practically three pieces to handle. The set can be put together on the ground, and raised into position with a minimum of difficulty.

Fig. 14 illustrates a form of construction adapted for lighter loads where the span is not too great to require more than an H-section as support. It consists of an H-section collar, H-section legs, simple base plates if required, and cast iron cap to distribute the load from the collar to the legs and having protecting lugs to prevent undue side motion. With this form of construction, H-sections are absolutely plain. They can be cut to length either at the shop or at the mines, as desired.

The history of these sections demonstrates that which has always happened in the history of all new ideas—a good idea brings with it a succession of others which were outside of the ken of its originator. When the H-sections were placed on the market their usefulness in other directions became plainly apparent. They will take their place with the ordinary structural shapes, heretofore rolled, in the construction of light columns for all sorts of purposes, and the present range of sizes is sufficient to construct an ordinary five- or six-story building. They will also be used for transmission line supports and for other purposes for which ordinary structural material, and indeed timber, is now employed.



THE AUDIFFREN REFRIGERATING MACHINE.

THE AUDIFFREN REFRIGERATING MACHINE.

NO ESSENTIAL change has been made in machines which produce refrigeration by alternate compression and expansion of liquefiable gases, since their introduction, thirty years ago. The gas (sulphurous acid, carbonic acid, ammonia, or methyl chloride) is compressed by a pump into a worm or other vessel, from which the condensed liquid, after cooling, flows into a second worm. Here the liquid evaporates, absorbing heat in the process, and the vapor is drawn off by the pump and again forced into the compression chamber. In order to prevent leakage of gas outward and of air inward the piston rod of the pump must work through a very tight stuffing box. Hence a great deal of power is wasted in friction, especially in small machines. The efficiency of the smallest machines is only one-third that of the largest.

Audiffren and Singruen have remedied this defect and rendered the efficiency independent of the capacity of the apparatus by inclosing the pump in the compression chamber. The compression and expansion chambers are vessels bounded by surfaces of revolution, hermetically closed, and rigidly attached to the horizontal driving shaft, which terminates in the interior of the expansion chamber. The pump is mounted in a frame which swings loose on the shaft and is kept vertical by a heavy mass of lead attached to the bottom of the frame. The pump is entirely surrounded by oil, which fills the compression chamber except at the bilge, where the liquid of condensation collects in obedience to centrifugal force. The shaft, beyond the pump, is hollow. It contains a pipe through which the liquid of condensation flows from the compression chamber to the expansion chamber, where it is vaporized. The vapor is drawn by the pump from the expansion chamber through the space surrounding this pipe in the hollow shaft. The compressed vapor discharged by the pump condenses on the cold wall of the compression chamber. The shaft turns on two bearings, to right and left of the compression vessel, and the two vessels turn with it, nearly half immersed in cooling water and the liquid to be cooled, which are contained in tanks provided with covers.

This ingenious arrangement eliminates not only the stuffing box but also most of the valves, cocks, and cranks of the ordinary apparatus. Even the safety valve becomes superfluous, for at a pressure determined by the weight of the lead attached to the pump the barrel can no longer maintain its vertical position but turns with the rest of the machine so no further compression can take place. Any leakage of the pump can only admit a little oil, which does no harm. The rotation of the two vessels is a further advantage, as it facilitates the transfer of heat from them to the cooling and cooled liquids in which they are partly immersed. Water can be frozen in from 3 to 10 minutes with this apparatus. The chief substances now employed can be used and little attention beyond the lubrication of the two external bearings is required.—Translated for the SCIENTIFIC AMERICAN SUPPLEMENT from La Science au XXme Siècle.

Irregularities in Cement Analysis.—The British Clayworker, in a recent issue, calls attention to the need for a standard method of cement analysis, showing the importance of doing away with the irregularities resulting from the different methods employed in various laboratories. The experience of a German firm is quoted as an extreme example of how great differences may result from variations in the methods of analysis. The firm stated that the cement to be used on a large work should conform to the standard French specifications. The work was begun, and on investigation it was found that the sample, according to the analysis made in the works laboratory, contained over 4 per cent of iron oxide, which was in excess of the amount allowed by the specification. Samples were then sent to the chief testing laboratories in Berlin, Wiesbaden, Zürich, Paris, and Madrid. The results obtained showed a wide variation in the percentage of the various constituents. The Paris laboratory gave the percentage of iron oxide as 3.10 while the Berlin analysis stated it to be 4.48; 19.36 was given by the Madrid laboratory as the percentage of silica, while the Paris analysis showed 21.34 per cent for this constituent. The Zürich results found Al_2O_3 to be 8.51 per cent, while the Berlin analysis gave the percentage of alumina as 6.57. The Madrid laboratory found the SO_3 content to be 1.46, and the Paris results showed only 0.62 for this constituent. These were the most important differences, though in no case was there even a reasonably good uniformity exhibited. Furthermore, the Zürich laboratory's results were wrong on their face, for they totaled 101.81 instead of 100. The results obtained by the German laboratories, presumably using the same methods, might have been expected to vary somewhat from those of the Paris and Madrid laboratories, but they did not even agree with each other. Serious litigation may result from such a lack of uniformity and it certainly would seem that the adoption of a standard method would be a wise step.

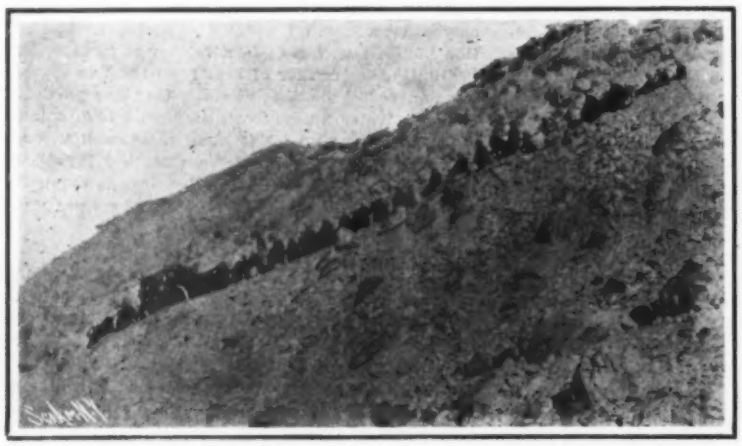
A new style of ditch-cutting machine, recently patented, was put into operation on a farm near Galt, Cal. Those who have seen it work, according to a consular report, assert that it will revolutionize the construction of all kinds of trenches, especially on marshy ground, where drainage is so necessary. The machine runs on its own track, the driving wheel being constructed on the endless-chain pattern, and so built that the machine can be moved over soft ground as fast as it cuts a ditch without making a visible depression. The ditch-digging apparatus is in the form of a wheel with open buckets for teeth, which take up the material and carry it to an elevator, which runs it out on an embankment at any desired distance, forming a bank the same height as the depth of the ditch. When seen at work it was cutting into hard upland soil, constructing a ditch 4½ feet in depth and 3 feet wide, moving at the rate of 5 feet per minute. With improved machinery it can, it is said, be made to cut at the rate of 12 feet a minute.

THE LIBYAN DESERT RAILROAD.

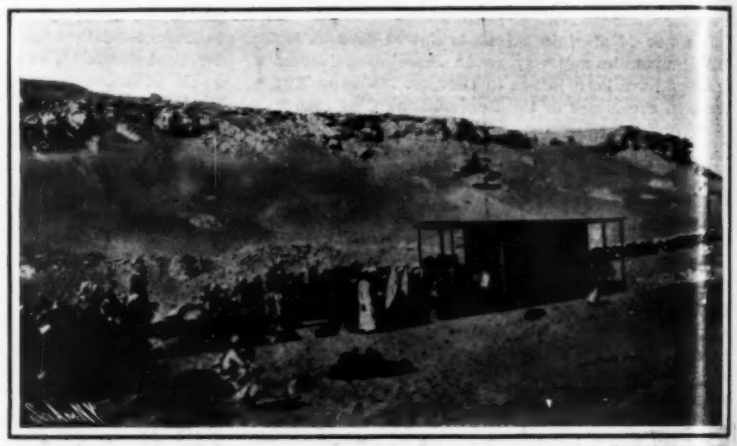
ITS FAR-REACHING INFLUENCE IN EGYPT.

BY OUR ENGLISH CORRESPONDENT.

AN important development which will exercise a far-reaching influence upon the commercial prosperity of Egypt and which will tend to increase the agricultural expansion of the country has been effected by the completion of the first section of the Libyan Desert railroad. By reference to the map of Egypt it will be observed that the country immediately fringing the western bank of the Nile is bounded by the vast desert. In the northeastern corner of this sandy tract, however, exists a belt of extensive oases (Kharga, Dakhla, Farafra, and Baharia) sweeping round in the form of a crescent from the south. These oases are of great extent and the abundance of water that is there to be found combined with richness of the soil renders the land valuable from the agricultural point of view. Moreover the oases are well region was undertaken and this proved that in addition to the extensive possibilities of cultivation in the raising of cereals, cotton, and other produce, the oases contained rich mineral deposits. Water was abundant, since, although the rainfall is practically *nil*, prolific subterranean supplies exist. The survey, however, demonstrated the fact that the construction of a railway across the intervening desert belt afforded no insuperable difficulties and so a company, the Western Egypt Corporation, was formed in London, which opened negotiations with the Egyptian government for the requisite franchise to construct a railroad connecting the national trunk system at Farshut with Kharga. The concession was duly granted, the exploiters receiving additional facilities for continuing the track through the other oases, then crossing the little distance above Farshut. The government, however, in order to bring the junction nearer the important station at Farshut undertook to widen the irrigation channel embankment just above Farshut, especially to carry the track. After leaving the river the railroad passes by way of Karnak village to Qara where the headquarters of the railroad has been established. Leaving Qara the line follows a westerly course to the Libyan Desert by way of the Wadi Samhud. For the first 10 kilometers the track is practically level, but a steady, easy grade of 1 in 50 is then encountered to kilometer 40 at the edge of the desert which is considerably elevated above the Nile valley. It was in connection with the conveyance of the constructional material that the greatest difficulties were encountered and long trains of camels and natives



A TRANSPORT TRAIN AT THE DESCENT INTO KHARGA OASIS.



BRINGING UP SUPPLIES TO THE RAIL-HEAD.

REMAINS OF THE TEMPLE OF HIBIS, KHARGA OASIS.

CLEARING OUT THE OLD ROMAN WELL IN THE MIDDLE OF THE DESERT.

THE LIBYAN DESERT RAILROAD.

populated by some 30,000 peaceful farming natives. Communication with the Valley of the Nile, however, is handicapped by a stretch of bleak arid desert, the narrowest stretch of which, between El Deir on the fringe of the Kharga Oasis and Farshut on the Nile, is some 80 miles in length in a direct line. Transport over this stretch could only be maintained with great difficulty by camels, the journey on the average occupying five days, while the sandstorms that prevail combined with the heat and the absence of rainfall rendered it imperative to carry adequate supplies of water for the needs of the caravan.

At the same time, however, the oases have always constituted an important agricultural and trading center, as the extensive archæological remains adequately testify; for the ruined temples show that they were successively occupied by the early Egyptians, Persians, Greeks, and Romans. Records prove that the oases of Kharga and Dakhla were inhabited as far back as B. C. 1500, and after existing for some years as separate colonies were united under the name of "Oasis Magna." Since the decline of the Roman Empire, however, the oases have been allowed to fall into desuetude. The natives have ceased to develop the resources of the areas except upon a scale sufficient for their own support.

A few years ago, however, a complete survey of the desert again from the north of the Baharia oasis and linking again with the State railroad in the Fayum.

The preliminary railroad survey showed that the only difficulty of any importance in connection with the scheme was the descent from the desert into the Kharga oasis which lies at a considerably lower elevation. The desert stretch itself comprises a limestone plateau fairly level throughout its whole extent, but the drop into Kharga is very sudden, necessitating a gradient of 1 in 40. This, however, was not considered too steep for narrow-gage operation. The narrow gage as employed upon the Delta and other Egyptian state railroads, viz., 0.75 meter, or 2 feet 5½ inches, was recommended and adopted, since thereby it became standardized with a large mileage of the national systems, facilitating renewals and repairs. The steel rails utilized weigh 36 pounds per lineal yard. In the Nile valley and the oases the rails are laid on creosoted timber cross-ties, and steel cross-ties upon the desert stretch. The track is single, and as there are no openings for development upon the desert section itself, is continuous thereover, with short side tracks or loops at intervals of ten miles to enable trains to pass one another. At these points water tanks have been established.

It was originally intended to effect a junction with the Egyptian trunk system near Abu Shusha some were pressed into service. Not only had the railway material to be brought up in this manner but also the Keystone drillers, the haulage of which over the desert was no easy task.

The desert itself is an undulating limestone plateau swept by sand and unrelieved by the slightest trace of vegetation or shelter. Sand storms are of frequent occurrence and rage with terrific violence. At the same time, however, the configuration of the ground is tolerably smooth and level, so that leveling and grading were reduced to a minimum. The maintenance of the commissariat was a perplexing problem, especially so far as water was concerned, every drop of which had to be brought up from the base, and the difficulties in this direction increased as the desert was penetrated. Between kilometers 40 and 145 the road is gently undulating, the grades being insignificant and all obstacles avoided as far as possible. About half way across the line skirts round a huge hill of sand or rather series of dunes of considerable extent the smooth sides of which present a picturesque relief to the prevailing level character of the country. Constructional work was carried out with great rapidity up to kilometer 77 when, unfortunately, active operations had to be suspended owing to difficulty experienced in securing delivery of the steel cross-ties *pro rata* with the rails from the manufac-

turers, several months elapsing before normal conditions were restored. But for this delay the two years occupied in construction would have been appreciably shortened.

After passing kilometer 145 the descent into the oasis is commenced, the declination extending over some 16 kilometers. The country through which this descent extends is extremely rugged and it proved the most expensive section of the railroad to construct. The railroad penetrates the oases, avoiding, as far as practicable, passage through the cultivated lands of the natives, to Kharga, the central town, which at present constitutes the inland terminus of the railroad. The total length of the track is 196.612 kilometers or about 122 miles. Alongside the track a telephone line has been built, this being carried forward simultaneously with the progress of the railroad so that the railroad was kept in constant communication with the base on the Nile edge of the desert. At every mile plug facilities have been provided on the poles to which a portable instrument can be readily connected. One of these instruments is carried on each train, both passenger and freight, so that communication can be secured with either terminus of the line in case of accident or any other emergency during the journey over the desert.

The railroad is now in operation. The engines are of tank and engine-and-tender design of great haulage capacity. All motion is incased to protect it from the sand. Adequate water facilities are provided, the water tanks being of large dimensions, but for precautionary purposes a water car is attached to every train. The total time occupied in the journey from Farshut to Kharga is about five hours, of which about three and a half hours are spent in crossing the desert.

In the course of building the line the old Roman well found about midway across the plateau was investigated and cleared out by the natives, while numerous other wells were sunk for charging the water tanks disposed at the loops or side tracks. While the line was under construction the Keystone drillers were hurried up to the oasis to carry out the preliminary boring operations. This work had perforcedly to be restricted, however, owing to the difficulties experienced in conveying the drillers across the desert, the camel transport by which it was effected being excessive.

The illimitable artesian supplies of water within the area of the oases considering the absence of rain (during 1907 only three slight showers fell in three days) constitutes a remarkable feature of the district. It is estimated that the output of the existing wells in Dakhla and Kharga approximates 7,062,800,000 cubic feet of water per year which is sufficient to irrigate 30,000 acres, the duty being 187.88 acres per cubic foot per second. It is considered that in all probability this subterranean supply is derived from the rainy districts of Darfur and from the swamps of the Bahr-el-Chazal flowing northward through the porous beds of the Nubian sandstone which have a general dip to the north. The water is kept down by impermeable beds of clay through which it rises under pressure to the surface directly the clay is pierced by the borings. The difference in levels between the water bearing stratum of the oases and the swamps of the Sudd district is over 1,312 feet. Hitherto practically the whole water supply has been derived from one or more beds of sandstone lying at an average depth of about 400 feet, and it is considered as quite probable that deeper borings would tap lower water-bearing areas giving a higher pressure and greater supply, which would be of service for irrigating the higher cultivable areas in the oases. Some idea of the fruitful yield of water may be gathered from the fact that there are several wells sunk by the early Egyptians and Romans which still yield over 500 gallons per minute. From the cultivating point of view the oases have one great advantage over the land in the Nile valley—they are independent of the time, volume, and duration of the Nile flood. Moreover the absence of rainfall renders the possibility of surface contamination impossible. The water is pure and palatable, freely charged with nitrogen, which rises in bubbles from the water as it issues from the wells. Its average temperature is about 85 deg. F.

The conveyance of the water from the bore holes to the land to be irrigated can easily and economically be effected. Channels are built with sand embankments, which necessitate but slight expenditure or care in maintenance and owing to the continuous yield from the bores a constant supply is assured. In some places copious supplies of water can be secured from comparatively shallow depths such as 20 or 30 feet. These shallow resources are freely tapped by the natives with their quaint boring appliances. Occasionally they will strike a rich yield, when they flee in terror convinced that a flood is upon them. A graphic impression of the extent of the water supplies may be gathered from the accompanying illustration of a lake that has been formed solely from the overflow of one of these artesi – bores.

The soil is rich and peculiarly adapted to the cultivation of various products. Cotton of various varieties thrives excellently and it is considered that this belt will exert a decided influence upon the extent of the Egyptian cotton growing industry. All cereals can be raised as well as varieties of fruits; also the eucalyptus, sisal, and acacia trees, while willows are being extensively planted along the banks of the irrigation channels so as to bind the friable soil together with their extensive fibrous root system. The date palm flourishes luxuriantly and as the Kharga fruit always commands a ready sale in the Egyptian and European markets its cultivation is being fostered.

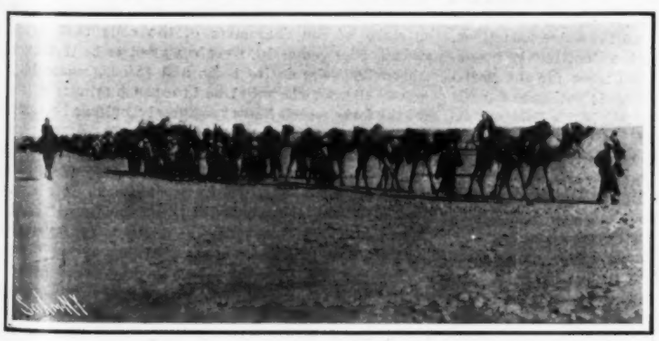
Apart from its arable potentialities, however, the country is rich in various minerals. There are inexhaustible supplies of phosphates and ochers which already have a high commercial value. The pottery clay beds surpass any that have hitherto been found in Egypt. Aluminous deposits of vast extent have been disclosed and these are available for the manufacture of aluminium sulphate by a simple process that can be worked by native labor. Alum leaching tanks have been built and abundant quantities of cobalt and nickel are found associated with the alum from which it can be recovered as a by-product. Auriferous strata have also been found. Owing to the corporation having secured the mineral concessions from the Egyptian government over a prescribed period the development of these resources is to proceed. Already arrangements have been completed for the installation of a modern Portland cement manufacturing plant at Qara where ample deposits of the requisite raw material are to be found alongside the railroad.

While the railroad will be dependent for its success to a large extent upon freight traffic Kharga promises

A CAMEL TRANSPORT TRAIN WITH TACKLE RESTING ON THE DESERT.

AN INSPECTION CAR AND NATIVES IN THE DESERT.

HAULING A KEYSTONE DRILLER ACROSS THE DESERT.



A CAMEL TRAIN TRANSPORTING RAILROAD MATERIALS

WORK TRAIN WITH GANGS OF NATIVES AT THE RAIL-HEAD

THE LIBYAN DESERT RAILROAD.

to become an important Egyptian health resort and visiting center. To the antiquarian it possesses particular attraction owing to the number of its archæological remains on every side which afford an interesting and valuable connecting link with the arts and civilization of early Egypt and its subsequent conquerors. Probably from the archæological point of view it is a serious rival to Philæ. The village of Kharga ten miles from the railroad terminus has its underground streets and cave dwellings; Nadura, two miles to the north, has a famous sandstone temple conspicuously situated on a hill of the time of Cæsar Antonius (138-161 A. D.) surrounded by a mud-brick wall; and the Christian necropolis comprising mud-brick mausolæa on the hillside, famous for its architectural beauty, with magnificent paintings in an excellent state of preservation in one or two of the buildings dating probably from the fifth and sixth centuries. The most distinguished remains, however, are those of the Temple of Hibis within half a mile of the railroad. This sandstone temple with its exquisite inscriptions and mural sculptures begun by Darius I (521-486 B. C.) and completed by Darius II (424 B. C.), and constituting the only Persian temple in the land of the Pharaohs, is in a magnificent state of preservation. The archæological remains also include the sandstone temples at Kasr el Cheuta, complete with sculptures and inscriptions, surrounded by a fortified village of mud-brick, and at Kasr Zaiyan a mud-brick ruin of a monastery showing the small cells with arched roofs, and the extensive Roman fortresses at El Deir and Ain um Dabadib.

Despite the exposed position of the railroad on the desert to sand-storms no difficulties have so far been experienced in maintaining the track. For the most part the violent storms have gathered the sand and swept it clear of the track, what little piling has resulted being against the outer surfaces of the rails leaving clear the inner face against which the flanges of the wheels run. It is found that a gang of thirty natives is adequate for the patroling of the track and the removal of any sand that may be deposited by the winds. Similarly but little interference has been experienced in connection with the maintenance of the telephone line skirting the track. The completion of the railroad, however, will not fail to exert a widespread influence upon the development of lower Egypt and constitutes the first important step in the extension of railroad facilities, apart from the trunk north-to-south system progressing toward the South African section of the Cape to Cairo line.

DARWIN AND AFTER DARWIN.*

THE NEW BIOLOGY OUTLINED.

BY PROF. HENRY EDWARD CRAMPTON.

THE most striking feature of animals and plants is their adjustment to their vital conditions. An organism that seems so sufficient unto itself, so capable and independent, is nevertheless inextricably interlocked with its surroundings, for its very substance is composed of materials which with their endowments of energy have been wrested from the environment. An animal that is pressed upon by the substances of the outer world, that is played upon by various energies, and is attacked on all sides by innumerable foes, finds itself involved in a warfare that is tragically one-sided; and it must prevail over all its many foes or it must acknowledge defeat and pay the penalty for unconditional surrender, which is death—so stern and unyielding is that vast totality we individualize as the environment. The generalized biological formula, then, for the turmoil of nature is *adaptation = life*.

Here then is the heart of the mystery. How has this universal condition of adaptation been brought about? What have animals within them that might determine their greater or less efficiency? What external influences, if any, are capable of directing the efforts of living creatures to meet their enemies? How are modifications perpetuated when they have arisen? To many of these questions Darwin, Weismann, Mendel, De Vries, and others have found answers, not complete or perfect, it is true, but they have relegated to the past the former reply that supernatural causes must be invoked to account for nature. Science is convinced that the study of nature's workings at the present time reveals natural factors which are competent to account for much of the wonderful process of evolution.

As everyone knows, the works of Darwin inaugurated our recent era in biology. In 1858, Darwin and Wallace announced the doctrine of natural selection, and in 1859, Darwin published the "Origin of Species," a book that has proved a veritable Magna Charta of intellectual liberties, for as no other single document before or since it has released the thoughts of men from the trammels of unreasoned conservatism and dogmatism.

What now, is the doctrine of natural selection, as Darwin propounded it? All animals vary; every individual differs from others of its kind, even from its closest kin and from its parents in some or many particulars and to different degrees. Whatever the causes, the fact of variation stands unquestioned. Some variations are of course due to direct environmental influence, and to these Buffon attributed an excessive importance; other deviations from the parental or average specific type are no doubt due to indirect effects of the environment, as Lamarck contended. But there are countless other variations that cannot be so explained, some of them indeed appearing before an individual is subjected to the action of the environment, and these are the congenital variations due to some constitutional even if unknown causes. These seemed to Darwin to be the most important in evolution.

The second element of the doctrine is that over-production, or rather over-*re*production, is a universal characteristic of living things. The normal rate of multiplication is such that any given form of animal or plant would cumber the earth or fill the sea in a relatively brief period of time. We now know that a bacillus less than 1/5000 of an inch in length multiplies under normal conditions at a rate that would cause the offspring of a single individual to fill the ocean to the depth of a mile in five days. "Slow-breeding man," wrote Darwin, "has doubled in the past twenty-five years." But excessive multiplication is checked by the third part of the whole process, namely, the struggle for existence, that fierce unequal warfare waged by every individual with its inorganic surroundings, with other species of living things, and with others of its own kind. Indeed, where members of the same species compete, the struggle ofter surpasses in ferocity the warfare with other organisms. Communal organisms only are in part exceptions, for in these the battle involves the clash of community with community more than it does the interests of the individuals of a single colony. To what, now, do these elemental processes lead? asks Darwin. Though all seek to maintain themselves, all cannot possibly live when only a few can find sustenance or can escape their enemies. Naturally those which possess any advantage whatsoever, that vary ever so slightly in the direction of better adjustment, would survive where their brethren perish. And this is nature's selective process, with its positive and negative aspects—the survival of the fittest and the elimination of the unfit. Now we can see why adaptation is a universal characteristic of species—there are no unadapted. If such there were, they have fallen long ago, and the world knows them no more. True it is that perfection is not attained by any creature, but it must establish a *modus vivendi* or it perishes. Thus, Darwin held, nature perfects species by dealing directly with favoring derivations that are mainly congenital, and so through these it selects the hereditary factors that determine favorable variations.

In one fundamental respect the doctrine is incomplete, as it fails to explain the causes for the variations with which selection deals. It accounts for the perpetuation of favoring variations, but it does not account for their inception. Because of this defect, investigators reacted from the academic discussion of Darwin's original doctrine, and returned to deeper and wider study of heredity and variation with brilliant success. Some neo-Darwinians have endeavored to make the selective process an originative influence—notably Roux, and Weismann in his theory of germinal selection. Darwin himself added the subsidiary process of sexual selection, which regards the preference by one sex of characteristics of the opposite sex as a conserving influence. But while such attempts have failed, zoologists believe, to explain the whole method of evolution, much of the process has been demonstrated more and more clearly with further study. The laws of fluctuating variations have now been formulated with mathematical accuracy, through the employment of the statistical methods used earlier by anthropologists like Quetelet. The studies of Galton, and Pearson, Boas, Weldon, and Davenport have demonstrated that structural and physiological characters of men, of other animals, and of plants as well, vary according to the formulas of chance or error—a result they say that follows from the combined influence of innumerable and independent factors. Variation is a natural phenomenon of chance. Furthermore, the reality of the selective process has also been proved by statistical methods. Bumpus' English sparrows, Weldon's snails and crabs, and many other cases show that the individuals which depart widely from an average condition, or that are uncorrelated in their organization, are marked for destruction.

In brief, while natural selection has not been established as in any sense an originative process, it has been demonstrated, I believe, as a judicial process. For we may liken the many varied vital conditions to jurymen, before whom every organism must present itself for judgment; and a unanimous verdict of complete or at least partial approval must be rendered, or the organism must perish.

The phenomena of biological inheritance, however, have demanded the greater attention of Darwinian and post-Darwinian investigators. A complete statement of the whole of evolution must show how species maintain the same general characteristics through inheritance, how the type is held true with passing generations, and it must also show how new characters may enter into the heritage of any species to be transmitted as organisms transform in evolution.

The earliest naturalists had accepted the fact of inheritance as self-sufficient. The resemblance between parent and offspring did not demand an explanation any more than variation. When Buffon, however, added the element of species transformation, he held that external influences could bring about a directly responsive organic change, which he assumed was inherited. Lamarck developed the well-known view, previously advocated by Erasmus Darwin, that indirect responses to the environment could be fixed in inheritance as so-called "acquired characters," meaning by this phrase that such characters are acquisitions during the life-time of an individual as the effects of disuse or unusual use, or of new habits. Coming again to Darwin, we find that he endeavored to support Lamarck's doctrine and to supplement his doctrine of selection by adding the theory of pangenesis. According to this every cell of every tissue and organ of the body produces minute particles called gemmules, which partake of the characters of the cells that produce them. The gemmules were supposed to be transported throughout the entire body, and to congregate in the germ-cells, which would be in a sense minute editions of the body which bears them, and would so be capable of producing the same kind of a body. If true, this view would lead to the acceptance of Lamarck's or even Buffon's doctrine, for changes induced in any organ by other than congenital factors could be impressed upon the germ-cell, and would then be transported together with the original specific characters to future generations. Darwin was indeed a good Lamarckian.

But the researches of post-Darwinians, and especially those of the students of cellular phenomena, have demonstrated that such a view has no real basis in fact. Many naturalists like Naegeli and Wiesner were convinced that there was a specific substance concerned with hereditary qualities as in a larger way protoplasm is the physical basis of life. It remained for Weismann to identify this theoretical substance with a specific part of the cell, namely, the deeply staining substance, or chromatin, contained in the nucleus of every cell. Bringing together the accumulating observations of the numerous cytologists of his time, and utilizing them for the development of his somewhat speculative theories, Weismann published in 1882 a volume called "The Germ-Plasm," which is an immortal foundation for the later work on inheritance. The essential principles of the germ-plasm theory are somewhat as follows: The chromatin of the nucleus contains the determinants of hereditary qualities. In reproduction, the male sex-cell, which is scarcely more than a minute mass of chromatin provided with a thin coat of protoplasm and a motile organ, fuses with the egg, and the nuclei of the two cells unite to form a double body, which contains equal contributions of chromatin from the two parental organisms. This gives the physical basis for paternal inheritance as well as for maternal inheritance, and it shows why they may be of the same or equivalent degree. When, now, the egg divides, at the first and later cleavages, the chromatin masses or chromosomes contained in the

* Abstract of a lecture delivered at Columbia University in the series on Science, Philosophy and Art.

double nucleus are split lengthwise and the twin portions separate to go into the nuclei of the daughter cells. As the same process seems to hold for all the later divisions of the cleavage-cells whose products are destined to be the various tissue elements of the adult body, it follows that all tissue-cells would contain chromatin determinants derived equally from the male and female parents. As of course only the germ-cells of an adult organism pass on to form later generations, and as their content of chromatin is derived not from the sister-organs of the body but from the original fertilized egg, there is a direct stream of the germ-plasm which flows continuously from germ-cell to germ-cell through succeeding generations. This stream, be it noted, does not flow circuitously from egg to adult and then to new germ-cells, but it is direct and continuous, and apparently it cannot pick up any of the body changes of an acquired nature; indeed, it is doubtful whether such changes can reach the germ-cells at all, for the path is not traversed in that retrograde direction.

It must be clear, I am sure, that this theory supplements natural selection, as it describes the physical basis of inheritance, it demonstrates the efficiency of congenital or germ-plasmal factors of variation in contrast with the Lamarckian factors, and finally in the way that in the view of Weismann it accounts for the origin of variations as the result of the commingling of two differing parental streams of germ-plasm.

At first, for many reasons Weismann's theories did not meet with general acceptance, but during recent years there has been a marked return to many of his positions, mainly as the result of further cytological discoveries, and of the formulation of Mendel's law and of De Vries's mutation theory. The first-named law was propounded by Gregor Mendel on the basis of extensive experiments upon plants conducted during many years, from 1860 on, in the obscurity of his monastery garden at Altbrünn, in Germany. It was rescued from oblivion by De Vries who found it buried in a mass of literature and brought it to light when he published his renowned mutation theory in 1901. Mendelian phenomena of inheritance, confirmed and extended by numerous workers with plants and animals, prove that in many cases portions of streams of germ-plasm that combine to form the hereditary content of organisms may retain their individuality during embryonic and later development, and that they may emerge in their original purity when the germ-cells destined to form a later generation undergo the preparatory processes called maturation. They demonstrate also the apparent chance nature of the phenomena of inheritance. I think the most striking and significant result in this field is the proof that a particular chromosome or chromatin mass determines a particular character of an adult organism, which is quite a different matter from the reference of all the hereditary characters to all of the chromatin. Prof. Wilson has brought forward the convincing data showing that the complex character of sex in insects actually resides in or is determined by particular and definite masses of this wonderful basis of inheritance.

Mendel's principles also account in the most remarkable way for many previously obscure phenomena, such as reversion, and again, the case where a child resembles its grandparent more than either of its parents; these seem to be due, so to speak, to the rise to the surface of a hidden stream of germ-plasm that had flowed for one or many generations beneath its accompanying currents. I believe that the law is replacing more and more the laws of Galton and Pearson, formulated as statistical summaries of certain phenomena of human inheritance taken *en masse*. According to Galton's celebrated law of ancestral inheritance, the qualities of any organism are determined to the extent of a certain fraction by its two parents taken together as a mid-parent, that a smaller definite fraction is contributed by the grandparents taken together as a mid-grandparent, and so on to earlier generations. But Mendel's Law has far greater definiteness, it explains more accurately the cases of alternative inheritance, and it may be shown to hold for blended and mosaic inheritance as well.

De Vries's mutation theory has already been explained in an earlier address by Prof. Richards.* It is clearly not an alternative but a complementary theory to natural selection, the germ-plasm and mendelian theories. Like these last, it emphasizes the importance of the congenital hereditary qualities contained in the germ-plasm, though unlike the Darwinian doctrine it shows that sometimes new forms may arise by sudden leaps and not necessarily by the slow and gradual accumulation of slight modifications or fluctuations. The mutants like any other variants must present themselves before the jury of environmental circumstances, which passes judgment upon their condition of adaptation, and they too must abide by the verdict that means life or death.

From what has been said of these post-Darwinian discoveries, the Lamarckian doctrine, which teaches that acquired non-congenital characters are transmitted, seems to be ruled out. I would not lead you to believe that the matter is settled. I would say only that the non-transmission of racial mutilations, negative breeding experiments upon mutilated rats and mice, the results of further study of supposedly transmitted immunity to poisons—that all these have led zoologists to render the verdict of "not proved." The future may bring to light positive evidence, and cases like Brown-Séquard's guinea pigs and results like those of MacDougal with plants and of Tower with beetles may lead us to alter the opinion stated. But as it stands now most investigators hold that there are strong general grounds for disbelief in the principle, and also that it lacks experimental proof.

The explanation of natural evolution given by Darwinism and the principles of Weismann, Mendel and De Vries, still fails to solve the mystery completely, and appeal has been made to other agencies, even to teleology and to "unknown" and "unknowable" causes as well as to circumstantial factors. A combination of Lamarckian and Darwinian factors has been proposed by Lloyd Morgan, Mark Baldwin, and Prof. Osborn, in the theory of organic selection. The theory of orthogenesis propounded by Naegeli and Eimer, now gaining much ground, holds that evolution takes place in direct lines of progressive modification, and is not the result of apparent chance. Of these and similar theories, all we can say is that if they are true, they are not so well substantiated as the ones we have reviewed at greater length.

The task of experimental zoology is to work more extensively and deeply upon inheritance and variation, combining the methods and results of cellular biology, biometrics, and experimental breeding. We may safely predict that great advances will be made during the next few years in analyzing the method of evolution; and that a few decades hence men will look back to the present time as a period of transition like the era of re-awakened interest and renewed investigation that followed the appearance of the "Origin of Species."

* Published in the SCIENTIFIC AMERICAN SUPPLEMENT.

THE LAW OF THE CONSERVATION OF ENERGY.

HOW MAYER DISCOVERED IT.

BY PROF. FLORIAN CAJORI.

In the small town of Heilbronn, in Württemberg, stands a monument erected to the memory of the physician, Robert Mayer. It was unveiled in 1892, just fifty years after the publication of Robert Mayer's first essay on the conservation of energy. His career as a scientific discoverer is marked by many pathetic incidents. After the study of medicine he was made sanitary officer on a Dutch vessel, bent for the East Indies. During the long ocean voyage on the slow sailing vessel he was left much to himself. He gave his leisure hours to the contemplation of scientific subjects. He had occasion to observe that, in tropical countries, blood taken from the veins of patients looks almost like arterial blood. He concluded that in the tropics less oxidation is necessary than in a cold climate, in order to maintain a uniform bodily temperature. There must be a quantitative relation between the amount of heat generated and the temperature in which we live. In cold, northern climates more heat must be developed for the maintenance of uniform bodily temperature. During the 219 days between February and September, 1840, spent on the water, Mayer dwelt in close intellectual communion with Nature, and she gradually revealed to him one of her most precious secrets. Upon his return to Heilbronn he kept on thinking. A moving body is brought to rest by friction; heat appears. Has the motion disappeared into nothing? Has heat sprung out of nothing? If not, then there must be an equivalence between the heat generated and the motion destroyed. *Causa æquat effectum*, "Cause is equal to effect," became his favorite axiom. At first he thought that kinetic energy varied as the velocity. Later he recognized his error and perceived its variance with the square of the velocity.

On June 16, 1841, he sent an essay embodying his new ideas for publication in Poggendorff's Annalen, but the manuscript was not published nor was it returned to the author. Thirty-six years later it was found among the papers of Poggendorff. In 1842 Mayer prepared a second short paper of seven pages and had the satisfaction of seeing it printed in Liebig's Annalen der Chemie. This was a happy time in his life, for at the very hour when he learned of the acceptance of his manuscript, he was bringing home his bride and presenting her to his aged parents. But it is one thing to secure the publication of a manuscript and quite another thing to get scientific men to read and study it. A new discovery necessitates a new language. A new language is not generally understood. The curse of Babel fell upon Mayer's paper: "Confound their language, that they may not understand one another's speech." Other papers were printed by Mayer as pamphlets in 1845 and 1848.

Something of the personality of Mayer may be gained from the following stories. During a hurried meeting with Mayer in Heidelberg once, Jolly remarked, with a rather dubious implication, that if Mayer's theory were correct water could be warmed by shaking. Mayer went away without a word of reply. Several weeks later . . . . he rushed into the latter's presence, exclaiming, "Es ischt so!" (It is so, it is so). It was only after considerable explanation that Jolly found out what Mayer wanted to say. Of metaphysics Mayer had no appreciation. Rümelin narrates that in 1841 Mayer borrowed from him a copy of Hegel's "Logik" and Hegel's "Naturphilosophie," but returned the books a few days later with the remark that he did not understand a word, and that he could not understand any part of it, were he to study it a hundred years.

For years Mayer was unable to bring his great discovery to the serious attention of scientific men. Later there followed controversies on his rights of priority. A gloom fell upon him through the death of two of his children. His mind became seriously affected, and on May 26, 1850, he unsuccessfully attempted suicide by jumping from a second-story window. In 1851 he was placed in an insane asylum, where he was cruelly treated. Two years later he was set free, but he never again regained complete mental equilibrium. Such is the pathetic story of the first discoverer of the conservation of energy.

In 1858 a few voices were heard in Germany in praise of Mayer, but the one who did most to bring him historical justice was John Tyndall, who in 1862 lectured before the Royal Institution on Robert Mayer. I shall remain silent on the extremely bitter controversy, between Tyndall and Tait, regarding Mayer's researches. Tait and William Thomson placed a low estimate on Mayer's work and brought the charge that Tyndall, by praising Mayer, was belittling the work of Joule. One would suppose that gross historical errors would have been eliminated by this time from a subject like the conservation of energy, about which so much has been written. Such is not the case. Prof. R. T. Glazebrook, writing in the great "Dictionary of National Biography" (article, "Joule"), said in 1892, just before the publication of Mayer's correspondence, that Mayer in 1842 endeavored to measure the heat produced in the compression of air, but committed the very serious mistake of assuming without experimental evidence that "all the mechanical energy spent in compressing the air was used in producing change of temperature."

This same criticism was passed upon Mayer by Joule, Tait, and Helmholtz. A fundamental question is here involved, but the charge is not true. As early as September 12, 1841, in a letter to his friend, Prof. Baur, Mayer explained Gay-Lussac's experiment of 1807 on the flow of gas into a vacuum, and drew upon it to complete his argument on the equivalence of the work of compression and the heat generated by the compression. Gay-Lussac had found that when a gas expands into a vacuum it undergoes no change in temperature large enough to be detected by his thermometers. Hence, during compression practically all the work done upon the gas goes to produce change of temperature, and Mayer's argument is sound. That the criticism of Mayer's reasoning is invalid is not generally known to recent writers on the subject, but can now be verified by any one who will examine Mayer's collected works and letters, edited by Weyrauch in 1893.—Popular Science Monthly.

ELEMENTS OF ELECTRICAL ENGINEERING.—XXIV.

ELECTRO-CHEMISTRY.

BY A. E. WATSON, E.E., PH.D., ASSISTANT PROFESSOR OF PHYSICS IN BROWN UNIVERSITY.

Continued from Supplement No. 1701, page 86.

THAT chemical action is often allied with electricity is one of the most common and yet inscrutable phenomena of nature. The simplest illustration is afforded by the primary battery. In this, zinc is dissolved and a current of electricity generated. With some solutions it is even necessary that electricity be allowed to flow as a criterion that the zinc be acted upon. The Leclanché cell is, for example, quite inert except when the electric path is complete. In a still wider sense, the storage cell is one in which the chemical action and the electric current are reversible and unavoidable.

With the recognition that as the result of the chemical action there remained within the cell a new set of compounds, Faraday, in about 1840, conceived the idea that by sending a current from some exterior source backward, as it were, through such a solution, the compounds should be split up, not necessarily into their original form, but into even more elementary substances. He examined a large number of metallic solutions, with the astounding result of discovering the two metals, sodium and potassium, and a quantitative law of action that has proved one of the most rigid and fundamental yet known to science.

To this process of electric analysis he gave the shortened and now well-known name of "electrolysis." The solution he called the "electrolyte," and the submerged terminals the "electrodes." He tried the same solutions with different kinds and also with dissimilar electrodes, and upon the result of some of his original researches modern commercial processes of electrolytic production and refining largely depend. Other allied names are "anode" and "cathode," meaning, respectively, the electrode by which the current enters and leaves the solution. The passage of the current is

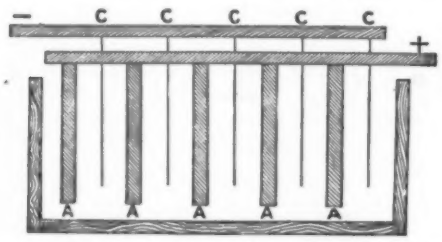


Fig 126.—Arrangement of Plates for Electrolytically Refining Copper.

imagined to break up the electrolyte into "ions," or material carriers of the current. In a given inorganic, or metallic solution, the hydrogen or metal is swept along with the current and appears at the cathode, while the rest of the elements pass in the opposite direction to the anode. In case the solution is a salt of one of the electrodes, the metal may be bodily removed from the anode and deposited upon the cathode, as is the familiar experience in electroplating. In other cases, as in a storage battery, there may be merely an oxidation at the cathode and a reduction to the metallic state at the anode. With solutions not aqueous, but with the materials in a fused state, and the current maintained through the mass when at red or white heat, a great extension to the possible combinations has been found.

The law discovered by Faraday was that in different cells, through which the same or equal currents were flowing, equivalent weights of any metal were deposited. He defined equivalent weights from purely chemical standpoints as meaning the atomic weight divided by the valency. For instance, with hydrogen taken as having an atomic weight of 1 and valency of 1, and consequently with equivalent weight of 1, chlorine with atomic weight of 35.5 and valency of 1 will have an equivalent weight of 35.5; copper with atomic weight of 63.5 and valency of 2 will have an equivalent weight of 31.75; aluminium with atomic weight of 27 and valency of 3, an equivalent weight of 9, and so on for all the elements, as may be gathered from any textbook on chemistry. The electricity being measured in amperes per second, or in "coulombs," as this unit is often called, the law reveals just how much metal may be realized from the passage of the current for any desired length of time. Careful determinations have been made of all the important metals, with the result that for one coulomb the figures for a number of these are, in milligrammes, as follows: Aluminium, 0.093; copper, 0.329; nickel, 0.303; silver, 1.119.

Another expression, or unit, that has been found convenient is the "gramme-equivalent"; by this it is meant to consider a weight of the given substance, in grammes, numerically the same as the equivalent weight. For instance, 1 gramme of hydrogen, 35.5 grammes of chlorine, 31.75 grammes of copper, and 9 grammes of aluminium would all be electro-chemically equivalent. Usually, when chemicals unite to form other compounds, there is a production of heat, as is well illustrated by the explosive violence with which hydrogen and oxygen unite to form water, or by the more simple burning of anything combustible, by

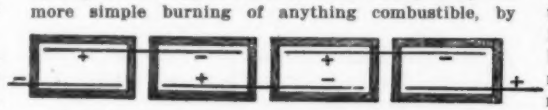


Fig. 127.—Diagram Showing Method of Connecting Copper Refining Tanks in Series.

which carbon and oxygen are brought together. Conversely, it is found that just as much heat energy must be expended in tearing these new compounds apart as was evolved in their formation. For gramme equivalents of compounds the same amount of heat energy is always required, and this has been found to be 96,540 calories. (A "calorie" may be defined as the amount of heat necessary to raise 1 kilogramme of water 1 deg. C. Sometimes the unit is based on a quantity of 1 gramme, but here the larger unit is taken.) For instance, the equivalent weight of common salt, sodium chloride, NaCl, is 58.5, and in the production of that number of grammes of the substance, 96,540 calories of heat were evolved; likewise, to separate it again into its component elements, that same number of heat units would need to be expended. Since heat is a form of energy that can readily be expressed in electrical units, the computation of the number of volts and amperes and the time required for any given reaction can be predetermined. Thus, while there may be some doubt as to the correctness of the theoretical speculations advanced, there is no opportunity of avoiding the rigidity of the numerical computations. As various illustrations of electrochemical operations will next be given, emphasis will be placed upon this commercial aspect.

One of the very first applications of electric currents was in electrotyping and plating with copper. With the principle extended to a large scale, and employing powerful currents from dynamos, the business of electrolytically refining copper has assumed very large proportions. In addition to the extreme purity of the product, the quantity of silver recovered from the deposit in the bottoms of the tanks goes a long way to pay the cost of the process.

This particular application is somewhat of a departure from the topic aimed at in the introduction, for copper is put into the cell, and copper taken out, and the solution is also a salt of copper. No new product is formed, hence, on the face of it, no energy might be thought needful. Still, the solution and the assemblage of bad contacts in the sets of plates make some resistance, so that about 0.2 volt per cell is the minimum found practicable. In order to allow a practicable dynamo, a large number of cells are connected in series, and voltages varying from 30 to 80 are employed.

Copper pigs as produced by the smelting furnaces are cast into plates of about the shape common for large storage batteries, and ⅜ inch in thickness, and, interspersed with similar shaped sheets of pure copper, but only about 1-20 inch in thickness, are assembled in wooden tanks as diagrammatically shown in Fig. 126. The thick plates marked *A* are the crude anodes, while those marked *C* are the pure cathodes. Current is supposed to arrive at the + pole, remove metal from the anodes, carry it through the copper sulphate solution, and deposit it upon the cathodes. Any impurities in the anodes, as they are reached, are supposed to fall by their weight into the mud or "sludge" that accumulates in the bottom. A plan showing the arrangement whereby any desired number of cells may readily be joined in series is shown in Fig. 127. The lugs from which the plates hang are made in slightly differing shape so that the anodes make contact with the + bar only, while the others touch the — only. The different plates are removed and new ones substituted one at a time, hence no interruption to the process need be tolerated except such as may be needed to care for the dynamos.

It has been found impracticable to start with metal of lower grade than ninety-eight per cent purity, else the impurities find their way into the product. A current density of more than 10 to 15 amperes per square foot is likely to give an irregular or granular deposit. A few other precautions need to be observed, i. e., to have plenty of sulphate of copper in the solution, yet not enough to crystallize out, to have enough sulphuric acid present to prevent formation of hydrated copper oxide, yet not so much as to be decomposed by the current and carry hydrogen rather than copper to the cathode; the solution is best kept warm say at about 95 deg. F.

As an example of the high attainments of the electrolytic method of refining copper, it may be stated that it is now common to exceed the famous standard established by Matthiesen, in 1865, and specifications are often written demanding a quality of conductivity of one hundred and one per cent or one hundred and two per cent, as based on that standard.

Means have been devised, and even perfected, by which other metals may be refined, but they are not largely employed, the reason being that sufficiently good and often cheaper chemical processes are already in use. In some cases, notably that of zinc, the reverse of the conditions that pertain to copper may be found, for this metal may be obtained from its ore advantageously by electrical means, and then the refining carried on by chemical means, such as fractional distillation. Gold, silver, and lead are satisfactorily worked by old methods.

With igneous solutions, as already mentioned, an extensive and somewhat undeveloped field has been entered upon. Not only have compounds been broken up and others formed quite beyond the reach or feasibility of chemical means, but some products not found in nature have been realized, and in this field of synthetic compounds the metallurgist may find his work approaching that of the organic chemist. In these fused solutions the result may be due to the action of heat alone, in which cases alternating current may be more available than direct, or in the solution there

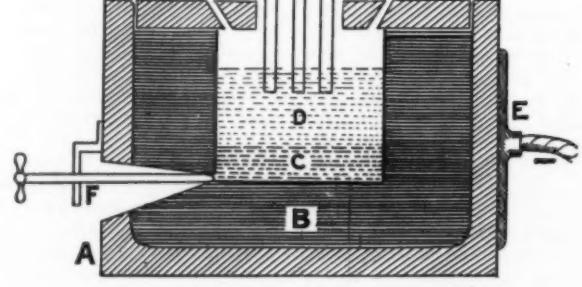


Fig. 128.—Héroult's Furnace for Producing Aluminium.

may be needed the electrolytic action, demanding, of course, direct current. Underlying the development of these processes is the scheme of the electric furnace, first made upon a practical scale by the Cowles brothers in this country and by Moissan in France.

For many years it was recognized that aluminium formed quite as large a constituent of the earth's crust as did iron, and was as valuable for many commercial applications; yet in trying to employ blast furnace methods for its reduction from its ordinary form in common clay, no furnace could produce or withstand the degree of heat needed—3,500 deg. C., or 6,332 deg. F., which is the temperature of the electric arc. Aluminium bronze, an alloy of copper, had been found to

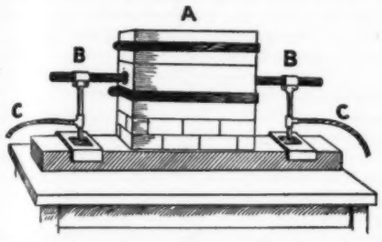


Fig. 129.—Laboratory Pattern of Moissan's Electric Furnace.

be a tenacious and durable metal, and the present successful methods of producing pure aluminium only aimed to produce this alloy. It is worth noting, too, that while the Cowles process proved too expensive and too unreliable in its product, it did show the way to the construction of a suitable electric furnace. Also, it was a historical accomplishment when Brush designed and built for this process his famous "Great Dynamo" with an output of 80 volts and 3,000 amperes.

The process closely followed by manufacturers of aluminium is that devised by Héroult, and a diagrammatic representation of his furnace is given in Fig. 128. An iron box, *A*, is lined with fire clay, and a space left within in which a mass of copper or aluminium, *C*, may be placed and electrically connected with the negative pole of dynamo. A bundle of carbons, *H*, forms the positive electrode, and the material to be fused is introduced at the top. In recent practice, the box is hollow, and through it water is kept circulating, so as to prolong the life of the casing, while the lining is somewhat protected by the congealed crust formed from the electrolyte itself. The process is continuous; for as fast as sufficient metal is produced, it may be drawn off at the opening shown, while fresh material is introduced at the top. To start the furnace, the carbons are brought into momentary contact with the lower electrode, with the result that some metal is melted, and as the vapor is formed, the separation may be still greater. As the temperature increases, the liquid aluminium runs down through the fused mass. At the temperature required it is to be supposed that the carbons would be short lived. This is true, and with the requirement that they be pure in order not to contaminate the metal, the cost of this item is not to be overlooked.

The material needed for the production of aluminium by these means is pure alumina, Al_2O_3, and it is best

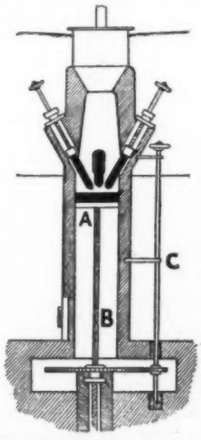


Fig. 130.—Calcium Carbide Furnace for Operating with Three phase Alternating Currents.

prepared from the particular kind of clay known as "bauxite." In this country large deposits are found in Georgia, and one of the largest manufacturers, the Pittsburg Reduction Company, obtains its supply from that source. The clay is sent to New Kensington, Pa., and there refined, the principal impurities to be removed being iron and silicon. The final condition of the material is a powder thoroughly dried by roasting and mixed with "cryolite," or the double fluoride of aluminium and sodium. This latter does not at all enter into the chemical reductions in the furnace, but merely acts as a solvent for the alumina, just as in the case of the copper refining apparatus, where the water acts as a solvent for the copper sulphate. Of course no trace of moisture must be allowed to find its way into the furnace, or a disastrous explosion would result, and ordinary metallic impurities would contaminate the aluminium resulting from the process. These preparations are rather expensive, representing about one-third of the total cost of the production.

In consequence of the fact that metal is to be deposited out of a solution on to the molten cathode, the current of electricity is needed not alone for generating the fierce heat, but also for effecting this deposition. Direct currents are therefore needed, and for the Niagara plant which was erected in 1894 and receives the two-phase alternating currents from the power company, large rotary converters were designed, being the largest of this class of machines the General Electric Company, up to that time, had designed. They have twenty poles, and an output of 400 kilowatts apiece; but to fit the frequency of 25 cycles used at Niagara, the speed is seen to be only 150 revolutions per minute. Later converters are designed with fewer poles and run at higher speeds.

The reduction in price of aluminium from that of forty years ago, when the metal was a curiosity selling at eight dollars per pound, to its present profitable rate of thirty cents, is one of the most notable accomplishments of the electric and commercial arts. If only the metal could be readily soldered, its usefulness would be immensely increased.

Among other products of the electric furnace calcium carbide may first be mentioned. This substance seems to have been first known to science in 1862, but was not of practical value until 1894, so the whole development of the industry that has been created for its manufacture and extensive adoption for artificial illumination dates from very recent times. It will be recognized that in consequence of the explosive violence with which this chemical is attacked by water it could not possibly be found in nature, and artificial production must ever be its only source. Before the electric furnace was utilized for this purpose, predictions were freely made and believed that the chemical and its product with water—acetylene gas—would always be too expensive for practical use. Though now quite reasonable in price and largely used for portable and isolated lights, still greater adoption of this dazzling white illuminant is inevitable.

The chemical formula of calcium carbide is CaC_2 and therefore it is seen that the simple ingredients of lime and coke should be able to produce it. The favorable conditions are a sufficiently high temperature, say 3,000 deg. C., and means for closely controlling it. As heat alone and not electrolytic action is needed, the alternating current answers quite as well as the direct and ordinarily is more available. Fig. 129 shows the construction of the furnace used by Moissan, and by many investigators since then, and commonly found in laboratories. The body, *A*, is made of blocks of lime scooped out in the form of a small dish, and into which the carbon electrodes are directed. Some space is left around these carbons to make room for the torrent of flames that emerge during the action of the furnace; and for the same reason the copper cables are attached to the lower ends of the columns where they may not so readily be melted. Lime is far better than fire clay for the receptacle; for in addition to its being more refractory, it is less of a conductor of electricity when highly heated. It will be remembered that, as illustrated by the principle of the Nernst lamp, some bodies that are complete insulators when cold quite lose that quality when sufficiently heated.

A commercial form of furnace for semi-continuous operation and adapted for three-phase alternating currents is shown in Fig. 130. In this a cast-iron disk is represented on the upper end of a screw and capable of being raised and lowered by movement of a hand wheel. The top surface is protected by a layer of graphite, and entering from above are the three carbon electrodes between which the arc plays and heats the surrounding mass. With the plate initially in contact with the carbons, the arcs are started, and then the mixture of purified lime and coke is slowly poured in at the top. As the reduction takes place, the disk is lowered, and more material added, until by the time the disk has reached its lowest position the bottom of the mass has cooled sufficiently to permit its removal by the opening shown in the side.

An estimate of several years ago shows the actual cost of a ton of calcium carbide ninety per cent pure to be twenty-eight dollars. One kilogramme of the pure substance yields about 350 liters of acetylene gas at atmospheric pressure, but the ordinary grade may not exceed 300 liters. The commercial value of the

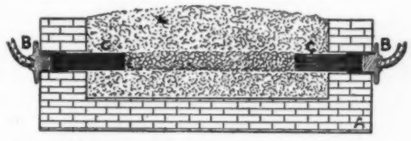


Fig. 131.—Furnace for Producing Carborundum.

carbide should be based upon this estimate of its gas-producing qualities.

A second product of the electric furnace, purely an artificial one, is known in the trade as "carborundum," and this highly effective abrasive has largely displaced emery. As the result of experimenting with a small furnace, Acheson, in 1890, produced what he thought was a compound of carbon and corundum (emery or crystallized alumina), and gave it this name. Difficulty was experienced in analyzing it; but when finally accomplished, the true constitution was found to be a union of carbon not with aluminium but with silicon. The present symbol is simply SiC, or by name, silicon carbide. A large furnace is required for the production of this article with rebuilding after every heat. The arc, however, is not directly present, but the large currents heat the entire poorly conducting mass to high temperatures. Fig. 131 gives a sectional view of the method of construction.

The furnace is about 15 feet long, 7 feet high and wide. At each end are copper castings, to each of which are attached sixty carbons 3 inches in diameter and 2 feet long. A central core of coke about 9 feet long and 2 feet in diameter connects the two groups of carbons so as to give an initial path for the current. Around this core is packed a mass consisting of about thirty-four per cent coke, fifty-four per cent sand, ten per cent sawdust, and two per cent common salt, weighing in all about 10 tons. If the entire mass were sufficiently heated to make the chemical change complete, upward of 4 tons of carborundum should result; as a matter of fact, only about 2 tons is actually realized, but that is not a bad outcome. The furnace is put together without mortar, and for the first two hours of the heating large quantities of carbon monoxide are evolved, and are allowed to burn over all the crevices in the walls. In twelve hours' time the entire furnace is red hot, but the current is kept on for twelve hours longer, when the current is turned off and the furnace is allowed to cool. About 4,000 amperes at 185 volts, alternating, are used, representing about 1,000 horse-power. When opened the product of the furnace is found to vary with the nearness to the central core. That on the outside is merely slag; the next, concentric with the core, is insufficiently formed for use as an abrasive, and is worked into the next charge; then comes the layer, or ring, of desired carborundum, about 16 inches thick. The crystals are small on the outside but increase in size as the core is approached. The core itself has been changed into pure graphite.

For utilizing the yield of carborundum, the crystals are broken up and crushed between rollers, washed with water and acid, dried and graded by sifting, or

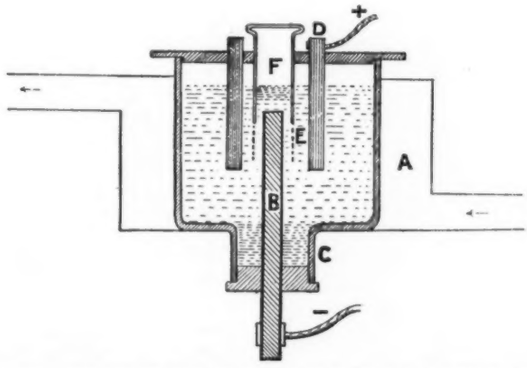


Fig. 132.—Castner's Electrolytic Method of Producing Metallic Sodium.

when left in water, by the settling process. The by-product, graphite, has been found of great use in the arts, as an effective substitute for the natural qualities. Diamonds or pure crystallized carbon have been sought in this furnace; but if produced there at all, they are of microscopic size and lacking in transparency. The concomitant condition of great pressure with high temperature is believed to be essential, and Moissan is now working in this direction.

In the alkali group of metals a new field for separation by electrolysis has been found, but curiously not essentially different in action from the simple arrangements devised by Faraday. The production of caustic soda, bleaching powder, and pure sodium, on a large scale, is carried on at Niagara Falls by the Castner-Kellner and allied processes. Common salt, mined at Saltville, Va., is sent there for separation by the action of the electric current. Of course the direct sort is needed, and is taken through the medium of rotary converters.

The precise method of working is kept secret, but an idea can be gained from some general publications of the company. The work is done in a tank having three compartments, the two outer being alike fitted with a carbon anode, while the central one has an iron cathode; the partitions are of slate, and enter grooves at the bottom which are filled with mercury. The liquids on the two sides of the partitions are therefore effectually trapped, but the electric current can readily pass from one to the other through the mercury. Salt and water are placed in the outer compartments; but water only, in the central one. By means of supporting the tank on a knife-edge at one end and resting on an eccentric at the other, a slight rocking motion is imparted for keeping up some agitation.

The chemical action can readily be followed. At the anodes salt is decomposed, liberating chlorine gas and delivering metallic sodium at the surface of the mercury. An amalgam results, but the current now tears the sodium out of the mercury and directs it toward the iron cathode. Sodium, however, reacts at once with the water, forming caustic soda and liberating hydrogen. After a sufficient degree of concentration of the caustic solution has been reached, it is drawn off, and the process repeated. The chlorine which was liberated is not allowed to escape, for in addition to its poisonous qualities it has commercial value. It is conducted away and absorbed by slaked lime, forming ordinary bleaching powder—chloride of lime. Indeed, the demand for the caustic soda and metallic sodium gives a yield of bleaching powder rather in excess of the market demand, and the manufacturers are now seeking to create artificial demands for it.

By evaporating the water from the solution, the solid caustic soda is obtained, and sold either in the form of pencils or coarse granules. Cans of the latter are ordinarily labeled "Potash or Lye." It is a common adage that the name is really a "lie," for the contents are not potash but soda. An investigation would show that sodium compounds, on account of their cheapness, have largely displaced the corresponding ones of potassium for use in the arts.

The actual demands for metallic sodium are small, but the electrolytic method devised by Castner is the only one now in commercial use. The diagram given in Fig. 132 represents the arrangement. An iron pot is set into a flue through which a blast from a fire is kept in the direction shown by the arrows, so as to bring the dry caustic soda to about red heat; at this temperature it is very fluid, like melted lead. Iron electrodes are used, both having their clamps well out of the direct range of the fire. The upper electrode is in the form of a cylinder with slots to allow circulation.

Within this electrode is a cylinder of wire gauze, *E*, hanging from the inverted collecting pot, *F*. When the current of electricity flows, fused sodium separates out and passes in the direction of the current toward *B*, and then rises into the pot, the gauze preventing it from actual contact again with *D*.

The decomposition of caustic soda, NaOH, necessarily liberates hydrogen; and when the cover of *F* is lifted for periodical bailings out of the sodium, there are likely to be slight explosions, but they do not seem to be dangerous. The Electro-chemical Company at Niagara uses about 700 horse-power in this sodium process, and the yield from this expenditure is about 360 tons per year. The metal is used in the manufacture of sodium peroxide, for the production of cyanides, for "quickening" mercury for gold amalgamation, but has no other considerable uses. Its great affinity for water, with consequent production of gas, may suggest interest in developing its possibilities for storage of energy for power purposes.

While it has not been considered necessary to include electroplating in this chapter, a few words may be said in explanation of the recent modification of that art known as "coloring." The color in general is supposed to be that of gold in various shades. Such infinitesimal thinness of gold is put on as to be unworthy of the name "plating," but the principal intention is to produce something that will last long enough to sell. For such articles as receive no actual wear, this color effect may often be sufficient. The art consists in using anodes not of pure gold, but of its alloys, and solutions containing things other than gold. Instead of very small electromotive forces which are suitable for depositing the pure metal, say not over 1 volt, 6 to 10 volts, or even higher values, are given, and the articles immersed for not much longer than an instant. The momentary rush of current carries along the base portions of the alloy and deposits them along with the precious, the results imitating in highly deceiving manner the common effects known in the trade as "Roman" gold, "green" gold, etc. For genuine plating, gold requires the lowest strength of current of any of the metals; this coloring process utilizes the highest.

THE RESPIRATION OF AN INLAND LAKE.*

WHAT OXYGEN MEANS TO INLAND WATERS.

BY PROF. E. A. BIRGE.

An inland lake has often been compared to a living being, and this has always seemed to me one of the happiest of the attempts to find resemblances between animate and inanimate objects. Unlike many such comparisons, which turn on a single point of resemblance and whose fitness disappears as soon as the objects are viewed from a different position, the appropriateness of this increases rather than diminishes as our knowledge both of lakes and of living beings is enlarged.

The lake, like the organism, has its birth and its periods of growth, maturity, old age and death; and this fact is an obvious one, for of all the larger features of the landscape, the lake is the youngest and the most temporary. Its birth lies in the recent past, and in no very long space of time its existence must come to an end. In any lake district, lakes may be found in all stages of maturity and decay, and many dead lakes will be seen—places where lakes once existed which are now extinct. Lakes show not only the cycle of individual existence, but also the rhythm of seasonal activity. The activity of the lake in summer, both physical and vital, contrasts sharply with its torpidity in winter. And the lake resembles the organism not only in its annual recurrence of activity. The comparison may be pushed further and extended to the minor fluctuations of the vigor of vital manifestations which characterize lake and organism alike.

In all these points, and in many others, the lake resembles a living being; but in no respect does it resemble an organism more closely than in the topic on which I am going to discuss, namely, its respiration. In this comparison, the resemblance is rather in processes and operations than in form. The lake is morphologically a very simple creature, resembling rather a gigantic amœba than a more highly organized being. Perhaps it would be better to compare the lake, for the purpose of this subject, not with the organism as a whole, but with the special respiratory substance of the animal—the blood.

Like the blood of the higher animals, the lake consists of an unorganized fluid—the plasma of the blood and the water of the lake—and of numerous organized and actively living parts—cells in the case of the blood, and the plants and animals in the lake. As is the case in the animal, the respiratory gases are absorbed and transmitted to the living structures by means of the unorganized fluid. It is my purpose to trace in outline the history of these processes and their result upon the activity of the lake.

The respiration of the lake, like that of the higher animal, may be divided into external and internal respiration. By the former we understand the absorption of certain gases from the air and the return of other gases to it, as well as the processes by which this exchange is effected. We include in it also the methods by which the gases are distributed in the lake and conveyed to and from the surface of the water, which takes them from the atmosphere and gives them back to it. By internal respiration we mean the gaseous exchanges which take place in the lake itself, between its various organisms and the water surrounding them. With these exchanges come the chemical processes by which the character of the gases is altered or new gases manufactured, in the course of the vital activities of the inhabitants of the lake.

The external respiration of the lake closely resembles that of the organism. The lake absorbs oxygen, carbon dioxide and nitrogen from the atmosphere, and returns to it nitrogen, carbon dioxide and sometimes other gases. The nitrogen absorbed by the lake, like that taken in by an animal, has very little or nothing to do with the vital processes. In autumn, as the lake cools, larger amounts of nitrogen are absorbed, according to the general law of absorption of gases. As the lake warms during the summer season, the capacity for holding gases in absorption becomes smaller and some of the nitrogen is lost. This process is a purely physical one and has apparently no influence on the life of any of the organisms whose home is in the water.

The relation of the oxygen to life is, however, far different, and the processes of external respiration are of prime importance to the living beings of the lake. Speaking roughly, and in terms of our comparison, we may say that an inland lake is an organism which takes one full inspiration in the fall, and another, less complete, in the early spring; that during the winter it does not breathe at all and during the summer has only a very shallow and imperfect respiration. As the lake cools in the fall the temperature becomes uniform from top to bottom at a date which will vary from late September to late November or early December, according to the area and the depth of the lake and the consequent temperature of the bottom water, the volume of water to be cooled, and the vigor of the cooling processes. When the temperature has thus become uniform, the water of the lake is readily moved throughout its entire depth by the wind. It is turned over and all parts of it are brought into contact with the atmosphere. As a result, inland lakes, even those whose depth is two hundred feet or more, become almost, or quite, saturated with oxygen at a temperature but little above the freezing point. This quantity amounts to about 10 c.c. per liter, or about 1 per cent by volume; nearly twice as much as the water will hold at the highest summer temperature. In this condition as regards oxygen the lake goes into winter quarters, becomes covered with a sheet of ice in our latitudes, and is, therefore, shut off until spring from all further direct connection with the atmosphere. During this period the stock of oxygen is used up to some extent, especially in the water adjacent to the bottom. But as the vital processes of both plants and animals, and also those connected with decay, go on slowly at the low temperature of the water in winter, the amount of oxygen thus consumed is comparatively small, and most lakes contain an abundance for all forms of life at all depths, except perhaps in the strata very close to the bottom. This statement, though generally true, will not hold universally. In some ponds which are shallow and contain a large amount both of living organisms and of decomposing matter, the oxygen beneath the ice may become wholly used up. We all know of lakes where, if a hole is cut through the ice in late winter, the fish will crowd to it for air so eagerly and in such numbers as to be forced out on the ice. There are on record cases where an unusual exhaustion of the oxygen below the ice of a lake has caused the death of most of the fish. Such cases, however, are not common, and in the great majority of lakes the consumption of oxygen in winter does not go far enough to affect unfavorably their living inhabitants.

Associated with this partial exhaustion of oxygen, there is an increase during winter of the amount of carbon dioxide—the main gaseous product of respiration. This is not present in any observable quantity in the lake at the time of freezing, but it increases during the winter and the quantity at the bottom may become very considerable. The amount will be, in general, proportional to the amount of oxygen used up. In the spring, when the ice has melted, the water of the lake is once more uniform in temperature. It is put into motion once more by the wind and all parts

* Address of the president at the thirty-sixth annual meeting of the American Fisheries Society.

of the water brought into contact with the air. The carbon dioxide, which has been accumulating during the winter, is discharged or used by plants and the lake again becomes nearly saturated with oxygen. But as the temperature in spring is higher than in the autumn, the amount of oxygen taken in is less, and since the temperature of the water continues to rise, the stock of oxygen is being diminished from this cause quite independently of any use made of the gas by the organisms of the lake.

The period of full oxygen saturation in the spring is a brief one in our climate. The season advances very rapidly and the surface water soon acquires a higher temperature than that at the bottom. This warmed water is, of course, lighter than the cooler water below and tends to float upon it. The difference in density thus caused makes it increasingly difficult for the wind to create and maintain a complete circulation of the water. For a time the action of the wind may continue to mix each successive stratum of water with that below it, the mixture extending to the bottom of the lake. But this action is a very different thing from a complete overturning of the water; and while it results in raising the temperature of the lower water, it does not carry freely oxygen to the bottom. Thus, when the surface becomes decidedly warmer than the water below it, the bottom water, though it continues to warm, is withdrawn from direct contact with the air and is therefore at a disadvantage in the matter of gaining a new supply of oxygen.

As the season advances this stratification of water dependent on temperature becomes accentuated, and the lake becomes separated into two parts: an upper warm stratum of nearly uniform temperature, beneath which lies the cold water consisting of a transition layer—the *thermocline*—in which the temperature is rapidly falling, and below this the mass of the cold water whose temperature ordinarily falls rather slowly with the depth until the bottom of the lake is reached. The thickness of the upper layer varies with the size of the lake, from ten to twelve feet to thirty or forty feet. It is present as a definite and permanent layer at a date varying with the area of the lake from late April to the middle of July. It increases in thickness after the cooling of the lake begins, but does not change much before that process commences.

This upper layer is subject to the direct action of the wind, is kept in circulation, and may be saturated with oxygen, or nearly so, but the only new supply of oxygen which the lower water can gain must come to it indirectly from the upper stratum. This condition of permanent stratification of the water comes on at the time when the life of the lake and its consequent need of oxygen are rising to the maximum, with the increasing warmth of summer and the development of life. The consumption of oxygen for the purposes of decomposition is also at a maximum. The separation of the lower water from the atmosphere in summer by a thick layer of warm water is therefore a much more serious thing than the separation of the water from the air in winter by ice. In winter the demand for oxygen is at a minimum and the stock contained in the water is at a maximum. In summer both of these conditions are exactly reversed. It is therefore necessary for us to inquire as to the means which the lake has for absorbing oxygen from the air and its means of transporting the gas from the surface to the place where it is to be used, and to note the efficiency of these processes as compared with the call for oxygen in the summer life of the lake.

The absorption and distribution of oxygen constitute one of the fundamental problems of life for any large and active organism. The difficulty of solving the problem is increased by the fact that no large reserve stock of oxygen can be maintained. In the case of a human being there may be a food supply in the tissues sufficient to sustain life for weeks, even though no new supply is taken in. There is water enough in the body to maintain life for days; but if the supply of oxygen is shut off, life can be continued only for a very few minutes on the stock of oxygen contained in the body. So narrow is the space between abundance of oxygen and death from oxygen starvation. In a cold-blooded animal—with which the lake ought to be compared—processes of respiration are slower, but the relative situation is not materially different. The result of these conditions is that in any large animal enormous surfaces must be provided for the absorption of oxygen and there must be a very perfect mechanism for its distribution. Such respiratory systems exist in a great variety of forms, many of which are extremely complex and efficient. In the case of man the absorbing surface of the lungs is said to amount to about two thousand square feet—an area as great as that of floor, ceiling and walls of a room 20 feet square and 15 feet high. The necessity for arrangements for a large absorbing surface increases with the size of the animal, since in a large organism the area of the general surface is far smaller in proportion to its mass than in a small organism of the same shape. In a lake, whose size is enormous as compared with that of any living being, the absorbing surface is very small as compared with its mass; being only the upper surface of the water. The lake is, therefore, at a great disadvantage in the matter of absorbing oxygen as compared with the animal. Still further, all higher animals, both cold-blooded and warm-blooded, contain in their blood some chemical substance which has a special affinity for oxygen and which can rapidly pick up large quantities of it. Such a substance is wholly lacking in the water of the lake, whose respiratory power is correspondingly small as regards both the rapidity with which oxygen can be taken up and the amount which can be absorbed. It is indeed true that water will absorb, according to the general laws of the absorption of gases, about twice as much oxygen as nitrogen under similar conditions. This fact allows the lake to take in a larger stock of oxygen than would otherwise be possible, and that part of the atmosphere which is dissolved in the lake contains about one-third oxygen instead of one-fifth, as is the case outside. But even this amount is very little in comparison with the enormous volumes which a substance like hemoglobin can take up. It is also true that the mass of the water of the lake, in comparison with the mass of the organisms which draw their oxygen from it, is relatively far greater than the mass of the blood with reference to that of the cells which take their oxygen from it. Yet is it none the less true that the supply of oxygen in most lakes is very small as compared with that of an animal, and the mechanism for renewing it is always very inefficient as compared with the demand for the gas.

The disadvantage of the lake in the matter of respiration appears still more clearly when we consider the means of transporting the oxygen from the region where it is absorbed—the surface—to the deeper parts of the lake, where much of it is to be used. The animal shows a complex and very efficient mechanism for the circulation of the blood; an apparatus whose complexity and efficiency are in large measure determined by the necessity for a rapid distribution of the oxygen and a rapid disposal of the gaseous wastes of the body. In the lake the means of transport are three: diffusion, by which the gas is slowly passed from point to point in the water independently of currents; currents produced by the wind; and convection currents, produced by the cooling of the surface water to a temperature below that of the water beneath.

Diffusion is a process which operates rapidly when the distances are minute, but whose efficiency decreases greatly as the distances increase. In our lungs, or the gills of a fish, for instance, where the distance between blood and air is measured in thousandths of an inch, the process of diffusion goes on with great rapidity. But where, as in the lake, the distances are measured by inches or by feet, or even by scores of feet, the process is practically worthless for the processes of distribution. By diffusion alone oxygen would penetrate the lake only to the depth of a very few feet in a whole season. While diffusion, therefore, plays an active and important part in the exchange of gases between the individual plant and animal and the water immediately surrounding it, it has little or nothing to do with the general circulation of gases within the lake.

During the fall, when the lake is cooling, convection currents aid materially in carrying oxygen down to considerable depths. The surface water, saturated with oxygen, cools, becomes heavier, and sinks, carrying the gas with it. The same process takes place at night in summer, but ordinarily to very small depths. In general, we may say that during early and midsummer, before the period of general cooling begins, these processes do not extend to greater depths than ten or fifteen feet. At the season, therefore, when vital processes are most active and the need for oxygen is greatest, convection currents afford a minimum of assistance in distributing it. The main reliance, therefore, for the distribution of oxygen is in the third factor, the wind. This, as already said, is very efficient when the lake is uniform in temperature; but during the spring, as the lake warms, it becomes increasingly ineffective, and during the summer its action is confined to the upper warmed layer of the lake, and the lower, cooler, water is wholly shut off from the direct influence of the wind currents.

These facts show that an inland lake has an extremely inefficient apparatus for absorbing and distributing oxygen, and the net result is that in many lakes the amount and character of the higher life which the lake will support is conditioned by the amount of oxygen which the lake contains rather than by the amount of food which it can produce. The oxygen in the lower and cooler water of the lakes cannot be renewed between spring and fall. This amount would be indeed ample to sustain a large amount of animal life in full activity. But its use cannot be confined to the necessities of ordinary life. The processes of decomposition draw upon it much more heavily than does the animal or the ordinary vegetable life. All the plants and animals of the upper water, which die and sink into the deeper strata, the leaves blown into the lake, and the material washed in from the shore, decompose in the cooler water and in the process of decomposition use up a great amount of oxygen. This depletion of the stock of oxygen goes on with a rapidity which varies with the amount of decomposing matter dropping into the lower water, which to some extent regulates the rapidity of decomposition, and with the depth of the water, on which depends the quantity of oxygen contained in it. Each of these factors may and does differ in different lakes, but the result is that in a very large proportion of our inland lakes the bottom water loses its stock of oxygen comparatively early in the season and becomes uninhabitable for higher animals. This fact excludes from our lakes a good many kinds of animals which they might otherwise support, and very greatly limits the quantity of the higher life which the lake is able to maintain. A lake which loses its bottom oxygen, for example, cannot support a fish such as the lake trout, which must retire to the deeper and cooler water during the summer. To causes such as this may probably be attributed a considerable number of our failures in the planting of fish in our inland lakes. From causes such as these, the whole of the lower water, containing half, or more, of the volume of the lake, may become uninhabitable during the season when life is most abundant; and the quantity of life which the lake supports may be correspondingly limited.

Still further, since the rapidity with which the oxygen is exhausted depends on the amount of material which is deposited in the lower water, those lakes whose upper water contains the greatest quantity of vegetable life, and which can therefore support the greatest amount of animal life, use up the oxygen of the lower water most rapidly. It looks, therefore, as if we were in a somewhat unfavorable situation as regards the possibilities of higher life in the lower water of inland lakes. These lakes whose food supply is such that they are capable of supporting large quantities of animal life—I may say for our purposes, large numbers of fish—are likely from that very fact to exhaust the stock of oxygen in the lower water, which thus becomes uninhabitable; while those lakes whose lower water is fully habitable are likely to be so poor in organic life that they can support only a limited number of fish. It may be that further study will show that this relation is not so unfavorable as it now appears, but at present we must face the probability that it exists.

A noteworthy exception to this statement should be made in the case of very deep lakes—lakes two hundred or more feet in depth—in which the quantity of the lower water is so great and the consequent amount of dissolved oxygen is so considerable that no ordinary amount of decomposing material can exhaust it or materially reduce it. This is the case, for example, with Green Lake (237 feet in depth) in Wisconsin, and the same statement would doubtless hold for the deep lakes of New York and similar bodies of water. Such lakes may support an abundant population of fish both in the warmer and in the cooler water.

INTENSIVE AGRICULTURE IN DENMARK.

DENMARK, which is not larger than the French province of Brittany, has a foreign commerce of more than $200,000,000 annually. In 1901, Denmark exported, in round numbers, 29,000 horses, 123,000 head of cattle, 111,000 tons of fresh and salt meat, and 79,000 tons of butter. According to the last census the country contained 487,000 horses, 1,840,000 cattle, 877,000 sheep, 1,457,000 hogs, and 11,553,000 hens. In 1906 the exports of fresh eggs amounted to 428 millions. The arable area amounts to 7 million acres, and the moorland has been reduced to one million acres. The average farm contains less than 8 acres. The cultivated area is distributed as follows: 41.5 per cent in grain, buckwheat, peas, beans, and vetches, 46.7 per cent in clover and grass, 5 per cent in potatoes and root crops.

M. Tisserand, in communicating these facts to the French agricultural society, described the condition of the Danish farmer, the abolition of taxes on small holdings, the agricultural schools and laws, state loans to farmers, the syndicates, and the establishment of a ministry of agriculture, with expert chiefs, a veterinary service and government inspection of butter. He also emphasized, however, the important part played by private initiative in the development of Danish agriculture. There are numerous general and local agricultural societies of all kinds.

These facts show how much science, patriotism, and the efforts of a free, enlightened, and industrious people can do to develop the resources of a country.

At recent gunnery practice on the British cruiser "Argonaut," 137 rounds were fired and 105 hits registered, an average of 6.56 hits per minute, with 6-inch quick-firing guns.

ENGINEERING NOTES.

Facing-point switches to the number of 1,078 were removed from the tracks of the Pennsylvania Railroad—lines east of Pittsburg and Erie—during the four years from January 1, 1904, to January 1, 1908, according to a recent compilation by the company. These were for the most part hand-operated switches, of which 743 were taken out entirely and 125 others replaced by trailing switches. Of interlocked facing-point switches, 198 were taken out and 12 changed to trailing. During the same period, however, 1,094 facing-point switches were added, but these are all interlocked. These correspond to a growth of over 500 miles of running track—7,599 to 8,114—with 409 new siding connections.

New surveys are to be made for a railway in a northwest direction from Omsk to Tyumen, and for another railway in a similar direction from Kurgan to Yekaterinenburg. The latter line will cross the boundary line between Europe and Asia. Both these projected lines will bring the Siberian Railway in the western part of Siberia just beyond the frontier station Chelyabinsk into far more direct communication with the rich mining districts of the Urals. The two northern points referred to, Yekaterinenburg and Tyumen, are already connected by a railway, and by way of Perm there will be established a rather shorter route for joining the Siberian Railway either at Kurgan or Omsk. Surveys were made for these railways in 1904; but the work was never carried out.

The saying of Sterne about doing some things better in France has acquired the force of a proverb. It is certainly true of the French mode of slaughtering cattle. Instead of allowing beasts to be killed in private places the French towns concentrate all the slaughtering in public "abattoirs." This allows of an efficient inspection of cattle and of the means of slaughtering in order to insure humanity and cleanliness. Paris was the first to establish abattoirs, which in course of time have become antiquated, and are considered inferior to those constructed more lately in Berlin, Hamburg, Leipsic, and Cologne. The Paris Municipal Council, with a public spirit that does them honor, are not afraid to borrow from their former enemies improvements which will better insure public health, and have decided to expend about $8,000,000 upon rebuilding the slaughter houses, carcase and cattle market of La Villette, in order to have an establishment not only equal, but superior to anything that exists in Germany. The council have intrusted preparation of plans to M. Leon Bonnenfant, the official architect and surveyor of the district in which the slaughter houses of La Villette are situated.

The University of Illinois Engineering Experiment Station has recently issued a bulletin entitled "Voids, Settlement and Weight of Crushed Stone," by Ira O. Baker. This bulletin gives the results of some experiments to determine the proportion of voids in crushed stone loaded by various methods in cars and in wagons, to find the amount of settlement during transportation in wagons and in cars, and also to obtain the relation between the weight of a unit volume of the solid stone and that of the same volume of crushed stone immediately after being loaded in various ways, into cars and wagons, and also after being transported different distances. Usually crushed stone is nominally bought and sold by volume, but really by weight, since in ordinary commercial transactions the weight of a cubic yard of crushed stone is assumed and the number of yards in a shipment is obtained by dividing the total weight by the assumed weight of a cubic yard; and yet there seem to have been almost no experiments made to determine the actual weight of a cubic yard of crushed stone under any particular condition. Apparently the only experiments heretofore made upon this general subject are a few brief ones upon trap rock, conducted by Mr. McClintock, lately president of the Massachusetts Highway Commission. An account of his experiments is presented and discussed in this bulletin, but the main features are an elaborate series of tests upon crushed limestone from Chester, Joliet and Kankakee, all in Illinois. All the results are summarized in a table which gives for different sizes of crushed stone the co-efficients by which to multiply either the weight of a cubic foot of the solid stone (or its specific gravity) to get the weight of a cubic yard of the crushed stone at the crusher and also at the destination, for stone from the three different quarries. This elaborate table is summarized in the following statement: The mean co-efficient by which to multiply the weight of a cubic foot of solid limestone to obtain the weight of a cubic yard of crushed limestone is as follows:

For ½-inch screenings.....15.5
For ½-inch to 2-inch stone.....14.6
For 2-inch to 3-inch stone.....15.2

For trap rock the corresponding co-efficients are as follows:

For ½-inch screenings.....14.6
For ½-inch to 1½-inch stone.....13.5
For 1½-inch to 3-inch stone 13.9

ELECTRICAL NOTES.

An electric railway is being built on the Zugspitze, the highest peak in the Alps, on Bavarian territory. Its height is about 10,000 feet. The railway will run to the summit, while a hotel will be built at the 7,000-foot level.

The Locarno-Pontebrolla-Bignasc is the second single-phase railway to be constructed in Switzerland. It is 169 miles long, and runs through tunnels the total length of which is 939 feet. There are twelve stations and stopping places. The gage is 39.37 inches, and the track is laid with 50-pound rails. A 5,000-volt single-phase current is furnished by the power house at Pontebrolla. The cars are equipped with 40 horse-power single-phase series motors capable of hauling a 55-ton train over the heaviest grade on the line at 11.2 miles per hour, and on a level at 18.7 miles.

During the second half of 1907 the public telephone system of Italy passed into the possession of the state, which promised cheaper telephones and a better service—not yet realized. The direct service between Rome and Palermo is still very unsatisfactory. A thicker wire is to replace the present one. At the present moment the following towns in Sicily are in telephonic communication with Palermo and each other: Acireale, Alcamo, Caltagirone, Caltanisetta, Castellamare, Golfo, Castrogiovanni, Catania, Cefalu, Girgenti, Leonforte, Messina, Mistretta, Nicosia, Noto, Porto Empedocle, Sciacca, Syracuse, Termini, Terranova, and Trapani.

In a method for the manufacture of aluminium—H. Herrenschmidt, French patent 383,554, January 10, 1907—crude bauxite is powdered and dehydrated. The hot material is mixed with boric acid or a borate, preferably borax—about 8 per cent—and a quantity of carbon—coke, charcoal, etc., calculated to be sufficient for the reduction of the iron and silicon contained in the bauxite. The mixture is fused in an electric furnace, the iron and silicon being reduced and forming compounds with boron, while the alumina is merely melted. The fused oxide is then run into a second furnace, or into another part of the first furnace, where it is reduced to aluminium as usual, after the addition of cryolite, etc.

At a recent meeting of the Institution of Mining Engineers, Mr. F. Keffer discussed the question of mining in British Columbia, and pointed out that it has practically displaced steam in the Boundary District. Power is supplied from a plant some 25 miles distant from the center of the district, and also from a station 85 miles distant. The former plant is situated at falls on the Kettle River, and can generate at low water from 2,000 to 3,000 horse-power, which is transmitted at 20,000 volts. The latter plant can generate from 12,000 to 15,000 horse-power, and the power available at the falls is said to be at low water 60,000 horse-power. The line voltage at present is 40,000 volts, although arrangements are made for bringing this up to 60,000 volts should occasion require. Some of the motors erected at the mines are as large as 600 horse-power, one of this size and another of 500 horse-power being used to drive air compressors. Motors up to 100 horse-power run the crushers, and several of the haulages are electrically driven.

An electric hygroscope of great sensitiveness is described by J. Poenchon in a paper read before the Académié des Sciences. In a circuit which includes a sensitive mirror galvanometer and a battery or dynamo of about 100 volts, is inserted a glass tube of the caliber of a test-tube and about 4 inches in length. The tube is silvered inside and out, but the layers do not communicate. The silvering stops half an inch from the farther end, but is brought up to the extreme edge at the other end which is used for the tests. The whole forms a very sensitive detector for the presence of vapor. The sensitive part is the open end of the tube with the two silver layers, and the two layers are thus separated by the thickness of the glass. When we bring near the end a body which emits vapors of any kind, the vapor condenses on the glass and gives a more or less conducting layer. Thus the current passes from one layer to the other and into the galvanometer which is in the circuit. When no current passes the spot of light of the galvanometer is fixed, but on approaching the body it is seen to move quickly, showing that the end of the glass tube allows the current to pass. This effect ceases as soon as the vapor-producing body is removed, and the spot of light comes back to its original position. The rapidity with which the modification of the surface of the glass is produced or dissipated seems to show that it is caused by imponderable traces of vapor. The end of the tube is better broken off and then finished with fine emery. In this case the apparatus is so sensitive that it shows the vapor from the hand when it is placed near it at half an inch distance. The effect varies according to the region of the hand which is presented to the tube, and while the back of the hand gives about two inches deflection, the end of the finger is much stronger, and the spot is deflected to the end of the scale.

TRADE NOTES AND FORMULÆ.

To Soften Hardened Rubber Stoppers.—Digest ... for about ten days in 5 per cent soda lye at a ... perature of about 104 deg. to 122 deg. F. Wash ... off, scrape off the soft outer layer with a blunt ... and wash in warm water.

Adhesive for Joining Leather Straps—Gilder's ... 250 parts, isinglass 60 parts, gum arabic 60 ... comminuted and boiled in water until a solution ... uniform consistency is obtained, then add venice ... pentine 5 parts, oil of turpentine 6 parts, alcohol ... parts.

Production of Inlaid Bronzes (Bronzes Incrust... (Inlaying of silver in dark-colored metal objects) ... The old process of making inlaid bronzes consists ... the preparation of each object, either by etching ... engraving, so that the hollows could be subsequently ... filled with silver, in the galvanic bath (silver deposit). The composition of the bath, as well as its treatment and that of the object is exactly the same as in ... troplating.—Werkstatt.

To Color Copper Vessels Reddish Brown.—1. Coat ... bright surface with a paste composed of 4 parts ... digris, 4 parts calcothar, 1 part horn shavings ... some vinegar, heat over a charcoal fire until the ... ing is dry and black and remove it by washing ... scrubbing. 2. Verdigris 2 parts, cinnabar 2 parts, ... ammoniac 5 parts, alum 5 parts, mixed to a paste ... vinegar and this applied to the copper. Heat over ... charcoal fire and repeat the operation until the ... sired shade is obtained.

Ornamentation of Rubber Articles.—Use oxidized ... preferably atmospherically dried oil varnish. Oil ... nish colors must therefore not be applied directly ... the rubber, but first to a conveniently flexible ... (paper, fabric, etc.), which is protected against ... penetration of the varnish by a coating of size, ... albumen, glue, etc. The designs thus produced ... completely dried in the air, then the dried colors ... softened by moistening with volatile hydro-carbons ... that dissolve rubber, like benzole, naphtha, etc., ... pressed against the similarly softened surface of ... unvulcanized rubber. After the evaporation of ... solvent, the backing of the colors is removed. ... canize the rubber.

Hardening of Small Tools and Articles.—In order ... to harden small objects that must not be distorted ... and in which a uniform hardness is a primary ... sideration, make a small iron box, with a handle, ... the size of the object; a suitable tin box can also be ... used. This is then filled with pulverized charcoal, ... which the objects, as near to the top as possible, ... where there are several articles with a space between ... them, are placed. In order to attain the proper ... a small piece of steel is laid directly upon the charcoal. When the steel shows the desired deep-red ... the cooling may be effected in luke-warm water. ... annealing is best effected in an annealing furnace. ... Werkstatt.

To Re-enamel Enameled Cooking Vessels When Worn ...—Remove the old enamel coating. In a Hessian ... cible, perforated at the bottom, melt together, in ... ordinary air furnace, 20 parts of pulverized cryolite, ... 8 parts china clay and 72 parts of calcined soda. ... parts of the mass thus obtained, after reduction, ... be mixed with 16 parts of soda, 20 parts of carbonate ... of potash and 28 parts potassium nitrate. The ... ject must first be coated with an aqueous, glutinous ... solution, for instance, a decoction of carragheen moss, ... and over this the above described mixture must be ... dusted. The vessels thus treated are heated in a ... muffle to a bright cherry-red heat. After cooling the ... vessels are laid in a dilute hydrochloric acid solution ... of 6 deg. B, to which, in order to prevent its attacking the iron, 4 to 5 per cent of a metallic salt, tin ... for instance, is added. The deposited slimy matter is ... removed by means of brushes; the vessels are rinsed ... in clean water and coated in the usual manner with ... new enameling. The above quoted proportions of ... cryolite and china clay can be replaced with chipped ... off enamel particles in the proportion of 33 parts ... chipped off enamel to 67 parts of soda and then, in the ... same manner, 36 parts of this mass are mixed with 64 ... parts of soda, 20 parts of carbonate of potash and 8 ... parts of potassium nitrate.

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